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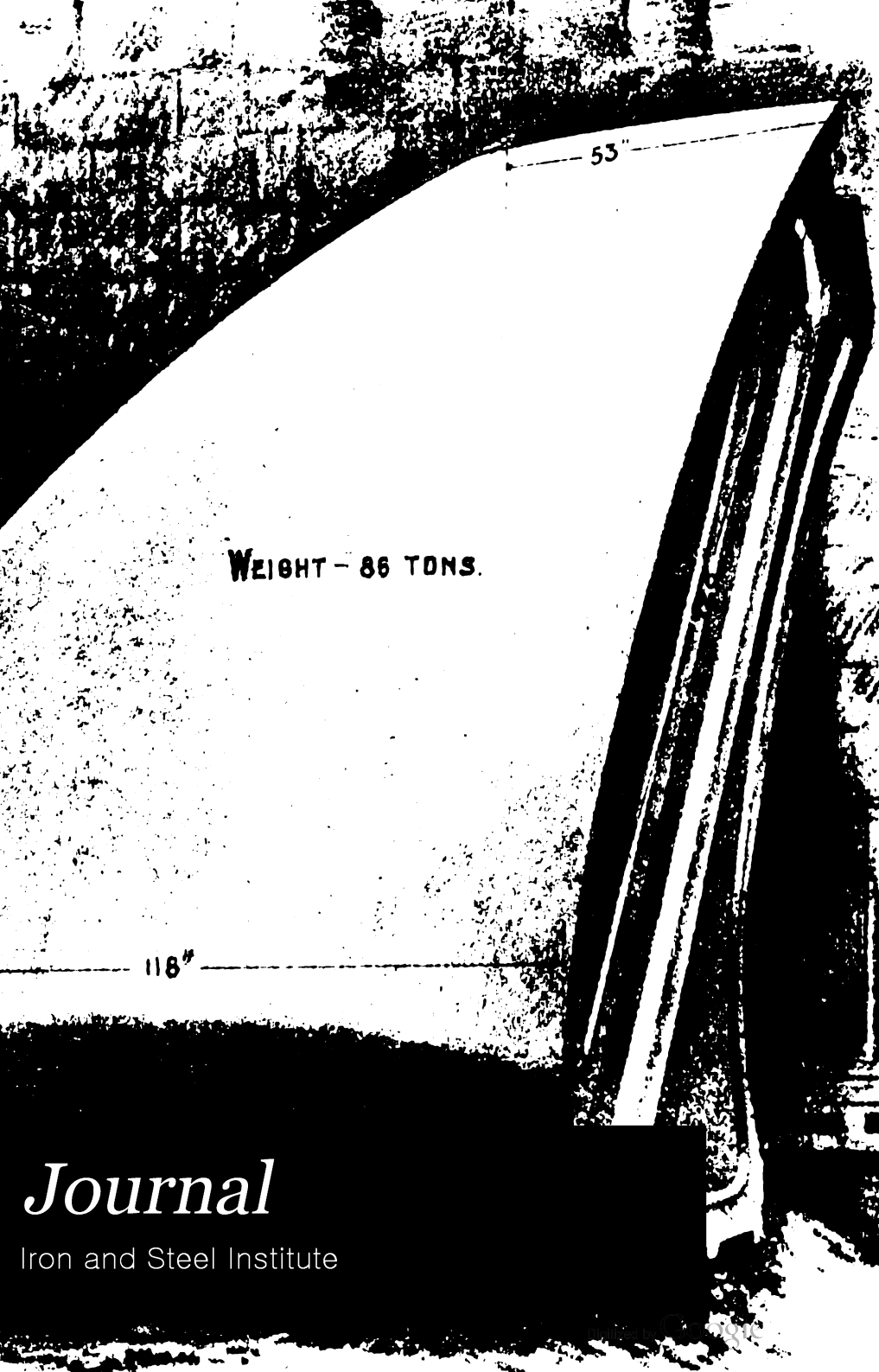
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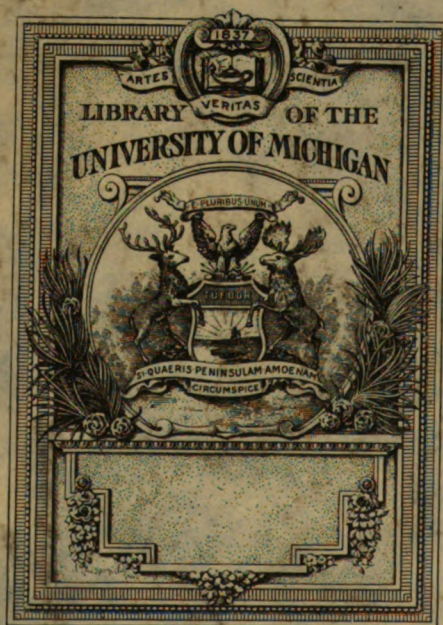
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„ „ paper on “ Practical Slide-Rule for Use in the Cal- culating of Furnace Charges,”	.	.	1
„ „ paper on “ Valves for Gas Furnaces,”	.	.	2

PROCEEDINGS

OF THE

IRON AND STEEL INSTITUTE.

ANNUAL MEETING, 1892.

THURSDAY, MAY 26TH.

THE ANNUAL MEETING of the IRON AND STEEL INSTITUTE was opened at the Institution of Civil Engineers, Great George Street, London, on May 26th—Sir FREDERICK A. ABEL, K.C.B., F.R.S., &c. (President), in the Chair.

The Minutes of the previous meeting were read, confirmed, and signed by the Chairman.

The CHAIRMAN nominated as scrutineers Mr. DAVID EVANS (Messrs. Bolckow, Vaughan & Co.) and Mr. R. EDMONDS (Royal Arsenal, Woolwich), who reported, on the completion of their scrutiny, that the following gentlemen had been duly elected :—

AS MEMBERS OF COUNCIL.

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EVANS, WILLIAM.....	Bowling, Yorkshire.
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Ordinary Members of Council.

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FORD, EDWARD LIVINGSTON.....	Youngstown, Ohio.
FOWLER, WILLIAM HENRY.....	Manchester.
HENDERSON, JAMES.....	Frodingham.
HEUSSEY, COMTE DU PONTAVICE DE.....	Albert House, London.
HIBBARD, HENRY DENNING.....	High Bridge, New Jersey.
LAMBE, GEO. CRAIG.....	Bilbao, Spain.
LOY, HARRY B.....	West Bromwich.
MATHER, ANDREW JOHN.....	Bradford.
MCLACHLAN, THOMAS.....	Bayswater, London.
ODENA, ANTONIO DE URUBURO.....	Bilbao, Spain.
OSBORN, SAMUEL.....	Sheffield.
PASSELECQ, ALBÉRIC-VITAL.....	Mons, Belgium.
RAUDON, WILLIAM JOHN.....	Handsworth.
RICHARDS, EDGAR JOSIAH.....	Barrow-in-Furness.
RIVERO, LUIS DE ARRIAGA.....	Bilbao, Spain.
SCHUMACHER, CASPER.....	Kalk, near Cologne.
SHEARD, ROBERT.....	Wakefield.
SIMPSON, HARCOURT TASKER.....	Sharrow, Sheffield
SUTOLIFFE, SAMUEL.....	Mostyn, North Wales.
TAYLOR, WILLIAM J.....	New Jersey.
TURLEY, THEODORE.....	Birmingham.
VERESTCHAGUIN, NICOLAS.....	Perm, Russia.
WHEATCROFT, ERNEST.....	Darnall, near Sheffield.
WOOD, JOHN.....	Wigan.
YOUNG, SEPTIMUS.....	Westminster, S.W.

The Report of the Council was read as follows:—

REPORT OF THE COUNCIL FOR THE YEAR 1891.

IN their last Report, the Council of the Iron and Steel Institute had to announce a net increase in the number of members of 146; an event unprecedented in the history of the Society, which was largely due to exceptional causes—notably the general prosperity of the iron and steel industries, and the inducements held out by the visit of the Institute to the United States of North America in the autumn of 1890.

The number of members has, on the other hand, made comparatively little progress during the year 1891. Seventy-nine new members were elected during that year, but there have been an unprecedentedly large number of losses; thirty-three members have died, twenty-one have resigned, and twenty-four have been removed from the register on account of other causes. The death-rate among the members has been much higher than in any previous year, and the number of resignations has been affected by the fact that a proportion of those who joined the Institute in the year of the American meeting evidently did so with the express object of participating in that visit, and have since withdrawn. Thirty-three members are proposed for election at the present meeting. This number would have been larger, probably, but for the depressed condition of the iron and steel industries generally, which has also affected the resignations and the necessary removals of the past year.

The following members of the Institute have died during the past year, viz. :—

HIS GRACE THE DUKE OF DEVONSHIRE (*Past President*).
LORD EDWARD CAVENDISH, M.P. (*Member of Council*).

George Adams, Wolverhampton.
James C. Arrol, Glasgow.
A. A. Dixon, London.
G. Dyson, Middlesbrough.
Robert Fleming, Glasgow.
Baron de Gargan, Hayange, Alsace.
Allan Gilmour, jun., Maryport.
The Earl Granville, K.G.

David Greig, Leeds.
Henry Howie, Harrington.
Jacob W. Hoysradt, New York.
Thomas W. Jowitt, Sheffield.
J. D. Larsen, Johannesburg.
Samuel Lees, West Bromwich.
P. S. Looker, London.
James Morton, Glasgow.

J. W. Cole, South Australia.	Richard Smith, South Kensington.
Julien D'Andrimont, Liège.	J. W. Sparrow, Beckminster.
Joseph Musgrave, Bolton.	R. George Tosh, Doncaster.
Hugh Neilson, Cambuslang.	Benjamin Walker, Leeds.
Samuel Osborne, Sheffield.	Thomas Walmsley, Bolton.
R. J. Ransome, Ipswich.	Joseph Whitley, Leeds.
Thomas Richardson, M.P., Hartle-	Lieut.-Col. C. H. Wilson, North
pool.	Wales.
Richard Sennett, London.	

The Institute has, it will be seen, suffered heavy losses during the past year, as well in the numbers of its members, as in the position and influence of some of the most prominent. The Council have especially to deplore the death of the first President, the Duke of Devonshire, who, although prevented by his great age, and by many duties and occupations, from taking that active part in the later affairs of the Institute that he did in its earlier history, yet never failed to exhibit the warmest solicitude for its welfare.

Lord Edward Cavendish had been for several years a member of Council, and had always, like his distinguished father, evinced an active desire to advance its interests. Earl Granville had been one of the original members of the Institute, which reaped material benefit from his early association with it, and from the interest he always took in its affairs. The deceased Peer attended the meetings of the Institute for the last time in May 1889, and on that occasion proposed a vote of thanks to Sir James Kitson for his presidential address.

The only changes that have taken place in the *personnel* of the Council during 1891 have been the addition to its number of Mr. Benjamin Hingley, M.P., upon the election of Sir Frederick Abel to the Presidency of the Institute, and the election of Mr. William Beardmore of Glasgow to fill the vacancy caused by the death of Lord Edward Cavendish.

As usual, two general meetings of the Institute were held during 1891, both of them in London. The Autumn meeting was held in the Metropolis in consequence of the inability of the authorities of Birmingham to arrange for a meeting of the Institute, in addition to the numerous engagements they had already on hand for the autumn of 1891; but thanks to the valuable aid rendered by the President, and the co-operation of Dr. Anderson, F.R.S., the Director-General of Ordnance Factories, and other officials at Woolwich Arsenal—where

the first day's sitting took place—the occasion drew together the largest gathering of members hitherto present at an Autumn meeting. The Council feel that the Institute is under great obligation to the President, and that it was largely due to his exertions that the Autumn meeting of 1891 was so successful. Besides inspecting the manufacturing departments of the Arsenal, the members were shown the working of quick-firing guns with smokeless powder at the proof-butts. Arrangements were also kindly made by the authorities concerned for showing members over the Royal Mint, the Dockyards of Portsmouth and Chatham, and other places of interest.

The following papers were read at the two general meetings of 1891 :—

At the Spring Meeting.

Tests for Steel used in the Manufacture of Artillery. By W. ANDERSON, D.C.L., F.R.S., M. Inst. C.E., Director-General of Ordnance Factories, Royal Arsenal, Woolwich.

Automatic Methods of Observation in the Use of the Le Chatelier Pyrometer. By Professor ROBERTS-AUSTEN, C.B., F.R.S., Royal Mint, London.

Note on the Micro-Structure of Steel. By F. OSMOND, Paris.

The Changes in Iron Produced by Thermal Treatment, II. By E. J. BALL, Ph.D., Royal School of Mines, London.

Economical Puddling and Puddling Cinder. By THOMAS TURNER, Assoc. R.S.M., F.I.C., F.C.S., Mason Science College, Birmingham.

A Graphic Method for Calculating Blast Furnace Charges, or "Burdens." By H. C. JENKINS, Assoc. M. Inst. C.E., F.C.S., Whitworth Scholar, London.

Recent Progress in the Manufacture of War Material in the United States. By W. H. JAKES, Bethlehem Iron Co., Bethlehem, Pa., U.S.A.

At the Autumn Meeting.

The Constitution of the Royal Ordnance Factories. By Dr. W. ANDERSON, F.R.S., Director-General of Ordnance Factories.

The Measurement of the Velocity of Projectiles. By Captain H. C. L. HOLDEN, R.A., Proof Officer, Woolwich.

The Manufacture of Continuous Sheets of Malleable Iron and Steel direct from Fluid Metal. By Sir HENRY BESSEMER, F.R.S.

Illustrations of Progress in Materials for Shipbuilding and Engi-

neering at the Royal Naval Exhibition. By W. H. WHITE
C.B., F.R.S., Chief Constructor.

On the Forging Press. By W. D. ALLEN, Sheffield.

An Undescribed Phenomenon in the Fusion of Mild Steel. By F.
J. R. CARULLA, Derby.

The Elimination of Sulphur from Pig Iron. By JOSEPH MASSENEZ,
Hoerde, Germany.

The Metallurgic Department of the Sheffield Technical School. By B.
H. THWAITE, Liverpool.

In their last Annual Report the Council announced that they had arranged for the publication of a special volume of Proceedings, forming a description and record of the visits and excursions made during the meeting in the United States. That volume has just been completed, and the Council are content that it should speak for itself. The principal contributors to the volume have been Sir Lowthian Bell (Past-President of the Institute), whose contribution is a valuable account of the metallurgical resources of the United States and their development, and one which is destined to be a work of permanent utility; Mr. Snelus, F.R.S. (Vice-President), who has written an interesting description of the Northern Excursion; Mr. John Birkinbine (President of the American Institute of Mining Engineers), who has supplied useful statistical and topographical notes upon American iron ore deposits, with special reference to the mines visited by the Institute; Mr. William Colquhoun of Cardiff, who has furnished technical accounts of the principal works visited, illustrated by drawings of furnaces and machinery; and Sir James Kitson, who, as President of the Institute during the memorable occasion in question, has supplied the preface. The preparation of the volume has occupied more time than was anticipated, but, apart from the fact that unavoidable causes of delay have arisen, the Council felt that, in the elaboration of so interesting and important a record and work of reference, the completeness of the volume ought not to be imperilled by hastening its publication.

The Council of the Institute have elected Sir James Kitson, Bart. (Past-President), to be their representative on the governing body of the Imperial Institute.

The Bessemer Gold Medal for 1892 has been awarded to Mr. Arthur Cooper, of the North-Eastern Steel Works, Middlesbrough, in acknowledgment of his arduous and successful labours in the construction and administration of the first important works in this country specially designed for the Bessemer basic process.

The statement of account for the year 1891 shows that the finances of the Institute are in a satisfactory condition. After providing for the extraordinary expenditure entailed by the preparation and issue of the special American volume, amounting approximately to £810, there remains a balance of income over expenditure of £164, 19s. 11d. But for this extraordinary expenditure the surplus would, of course, have been £974, 19s. 11d., being the largest that we have ever had. The total income from members' subscriptions during the past year has amounted to £3063, 18s., as compared with £2971, 10s. in 1890, being an increase of £92, 8s., and giving the largest income from subscriptions hitherto received. The sound financial position of the Institute may be further indicated by the fact that the total income has advanced from £3024, 13s. 11d. in 1887, to £3742, 6s. 10d., being an increase of annual income within five years to the extent of £717, 12s. 11d. It is a satisfactory indication of the importance which the Society's work has acquired in the opinion of those interested in practical and scientific questions relating to Iron and Steel, that the income from the sales of *Proceedings* to the general public has been steadily rising.

The autumn meeting will be held in Liverpool, which was last visited by the Institute in the year 1879.

The retiring members of Council are :—

Vice-Presidents.

Sir J. G. N. Alleyne, Bart. Mr. Wm. Whitwell.
Mr. Wm. Evans.

Members of Council.

Mr. W. H. Bleckly. Mr. P. C. Gilchrist.
Mr. W. T. Crawshay. Mr. Alfred Hewlett.
Mr. James Riley.

Other names having been submitted, ballot-lists have been issued, as required by the rules.

Mr. DALE (Hon. Treasurer) submitted the Financial Statement (see p. 261).

The PRESIDENT said it was his duty as President and Chairman of the Council to move the adoption of the Report and the Financial Statement just read. It was not necessary to detain the members by any long comments. One or two of the points dwelt

upon in the Report would be alluded to in the few remarks which he should presently submit.

The Report generally was, moreover, sufficiently explanatory to render any further remarks unnecessary. They might, he thought, congratulate themselves upon the comparatively prosperous financial condition in which they found themselves at the end of the year, and especially because it afforded them the means, without any trouble or anxiety, of meeting the expenses which he was quite sure they had most gladly incurred in the publication of the special American volume, of which he should have something to say in his address. It was a good thing to know that this somewhat heavy expenditure could be met without embarrassing their existing finances in any degree whatever, and that after this expense had been completely met there was a small surplus in hand at the end of the financial year. He begged to move that the Report of the Council, and the statement of accounts for the year 1891, be received and adopted.

Mr. ANDREW CARNEGIE seconded the motion, and said he desired in doing so to congratulate the Iron and Steel Institute on an experience which, he thought, during the present year, was unique in regard to anything connected with either iron or steel—that of being in possession of a large surplus in proportion to the capital, and with the future amply provided for.

Sir JOSEPH PEASE, Bart, M.P., said that a motion had been placed in his hands which he had great pleasure in proposing. He always rose in that assembly very much encumbered by the native modesty which characterised him, for he felt that he was addressing a gathering of very distinguished scientific and practical men, while he belonged to what he might call the inferior order of clergy—those who had more to do with finding the capital than finding the brains. They were practically divided into three classes—those who found the brains, those who found the money and brains, and those who found the money without the brains; and there were also the working men who found the sinew by which so many of their labours were carried on. To make the body complete, he supposed they might, too, be considered as being

divided into those classes. He therefore had very much pleasure in proposing that the best thanks of the meeting be given to the President, the Honorary Treasurer, and the Council for their services during the past year. Without their brains, and the brains of the members generally, the manufacturers of the country would have been even in a worse position than they had been during the twelve months under review. To their steady application of the practical scientific rules of iron-making they were all very much indebted. Indeed, without their brains, capital would be useless, and labour would degenerate into poverty. At the head of the Institute was one of the most distinguished men of the scientific iron-making world. Although it was not his (Sir Joseph Pease's) good fortune to be at Woolwich, he understood that the visit to the Arsenal was one of the most interesting that had hitherto been made by the Institute.

Mr. W. G. AINSLIE, M.P., seconded the motion, which was unanimously adopted.

The PRESIDENT, on behalf of his colleagues and himself, desired to acknowledge very briefly the kind expression that had been given to the appreciation by the members of the Council's endeavours to make themselves useful to that flourishing Institute. Year after year it was a great gratification to men who had known the Institute from its infancy, had helped to establish it, and had contributed to its success, to do anything they could to promote not merely the interests of the meetings, but the general welfare of the Society, and thus, indirectly, the interests of its members.

THE BESSEMER GOLD MEDAL.

The PRESIDENT then presented the Bessemer medal to Mr. Arthur Cooper of Middlesbrough. In doing so, he said it was his pleasant duty to hand the medal this year to a member who had identified himself with one of the most important advances in the manufacture of steel, viz., the basic steel process. It might be said that to Mr. Cooper was in a very large degree due the

success which, by rapid strides, had been achieved by that process. Mr. Cooper, in conjunction with Mr. C. B. Holland, very shortly after the reading of the first paper on the process by Messrs. Thomas and Gilchrist, in 1879, began to make experiments on the basic process. Small works were established for the production of basic steel at the works of Messrs. Brown, Bayley & Dixon, of Sheffield; and in December 1880 (within about a year of the reading of the paper by Messrs. Thomas and Gilchrist), Messrs. Cooper and Holland read a most interesting paper at the autumn meeting of the Institute, in which they recounted the success of their first experiments. Those experiments developed into practical results very rapidly, and not long afterwards, when the North-Eastern Works were established at Middlesbrough, Mr. Cooper was at once sought to undertake their direction. He believed that his operations had given an uninterrupted record of practical success. Indeed it might be said, that the North-Eastern Works had really been the nursery of the basic process. From time to time, through Mr. Arthur Cooper's arduous and successful labours, the process had been developed by various means, until it had attained an acknowledged and thorough success. He would now hand to Mr. Cooper one of the greatest distinctions attainable in connection with the metallurgic arts—the medal which Sir Henry Bessemer had placed at the disposal of the Institute, with the object of enabling the Council fitly to acknowledge such eminent services as those which Mr. Cooper had rendered to the iron and steel industry.

Mr. ARTHUR COOPER said that he was deeply sensible of the very kind way in which his merits had been referred to. He could not help thinking that they had been very much over-rated, and that in deciding to add his name to the list of the twenty illustrious men who had preceded him in receiving that very high honour, the Council had looked upon his qualifications with very kindly and very lenient eyes. At any rate he was fully conscious of the fact that his proud position that day was not altogether due to his own individual efforts, but rather to the kind assistance and support which he had received from his friends, from his colleagues, and from his staff. Amongst the former he wished to

mention the name of Mr. Ellis of Sheffield—under whose tutorship, some twenty-three years ago, he first became acquainted with the Bessemer process—as, during the time that he occupied the position of Bessemer manager at the Atlas Works, and ever since, he had received the greatest kindness from Mr. Ellis. In the same category he would mention Mr. Holland, under whom the early experiments with the basic process, referred to by the President, were made. He might next mention Mr. Sidney Thomas, one of the best, brightest, and kindest of men that the Institute had ever known, whose premature death, deplored by all who knew him, was not only a loss to his country, but to the entire metallurgical world. He would also express his indebtedness to Mr. Gilchrist, Mr. Riley, and the remainder of his friends and colleagues, and to his staff, all of whom had assisted him in obtaining this great mark of their favour. With regard to the basic process, it was not necessary to say much, because, as soon as their works were got into full operation, he had the honour of reading a paper before a meeting of the Institute at Chester, in which he minutely described not only the works, but their products as well.

It should not, however, be thought that all had been plain sailing. Such was by no means the case. Notwithstanding the experience of other works, which had been placed at his disposal—notwithstanding his own experience in Sheffield, and the kind assistance of the patentees, there was not, at the time they commenced operations, sufficient practical knowledge to determine the lines on which the process could be carried on with commercial success. That knowledge was only obtained after many months of fighting with details, and after the expenditure of many thousands of pounds. Eventually, however, they got into smooth water; and in order to give some idea of the extent to which the process had been developed, he might mention that, since they commenced operations, not quite nine years ago, they had made very nearly $1\frac{1}{2}$ million tons of ingots, all of which had been worked up and disposed of. Their trade was not decreasing, so that, whatever might have been the position of the process when they first took it up, it was now a well-established and appreciated process by those who understood it, and had taken the trouble to test the products for themselves.

He now came to the most difficult portion of his task—to find words adequately to express his gratitude. He need not say that that beautiful medal, founded by one who must always be regarded as one of the greatest benefactors of the century, was not only gratefully received but would always be most highly prized by him. He begged to tender his heartiest thanks, not only for the great compliment paid to his friends, his colleagues, and his staff, but also for the very great distinction—the greatest in their power to bestow—that had been conferred upon himself.

The PRESIDENT then delivered the following address:—

PRESIDENTIAL ADDRESS.

By SIR FREDERICK ABEL, K.C.B., D.C.L., Sc.D., F.R.S.

WORDS of sorrow, sympathy, and regretful retrospect are inseparable from the few remarks with which I would open the business of the Iron and Steel Institute at this the twenty-third annual gathering of its members.

The heavy affliction which has visited our illustrious Honorary Member, the Prince of Wales, aroused throughout the nation sentiments of deep sorrow and heartfelt sympathy for the parents, the grandmother, and the betrothed of the young Prince, whose charming character and truly affable disposition endeared him to all with whom he was brought into contact.

Whilst, by the death of the Duke of Clarence and Avondale, the country has been deprived of one who appeared destined to be its ruler, and the development of whose character was therefore watched with anxious interest by loyal and patriotic subjects of the Crown, the illustrious bearer of another ducal title, who has recently passed away at a ripe old age, impressed his contemporaries from the very beginning of his career by his genius and his force of character, and by a rare and happy combination of high intellectual power and exceptional business capacity. An ardent student of mathematical and natural sciences, and a keen cultivator of their practical applications, the career of the late Duke of Devonshire stands out prominently among those of the many distinguished men of whom the country has had to deplore the loss during the past twelvemonths, as having been intimately identified with the great progress which has been made of late years in this country in the extension and general advancement of scientific teaching. His wise munificence in the establishment of the Cavendish Laboratory in Cambridge University, and the important part which he took in the labours of the Royal Commission on scientific instruction and the advancement of science, are illustrations of his active participation in a movement of most vital

importance to the maintenance of our position and influence among nations.

The Duke's ready consent to fill the post of first President of the Iron and Steel Institute demonstrated his appreciation of the high importance to be attached to the successful foundation of an organisation of which he predicted that it would prove "a powerful instrument for the advancement and progress of the iron and steel trade of Great Britain, by promoting intercourse and interchange of knowledge between its members,"—a prediction which was speedily and amply fulfilled.

Another great bereavement which the House of Cavendish sustained, not a year before the death of our first President, was an event which caused sincere sorrow to the Council of the Institute; for the late Lord Edward Cavendish was, like Lord Frederick, a member of their body at the time of his death, and his colleagues held him in high esteem for his affability and unassuming sagacity.

Our unusually heavy losses by death during the past official year include two other very prominent members, to whom the retiring President of last year, Sir James Kitson, made graceful allusion in his valedictory observations. Not only as an honorary member, but also as one who was personally much concerned in the subjects dealt with at our meetings, the Earl Granville evinced a keen interest in the Institute's proceedings. But no less attractive to his highly cultured mind were all subjects relating to the advancement of science and of its practical applications, and his versatility in these directions lent an additional charm to the society of this accomplished statesman, polished orator, and most high-minded and courteous gentleman.

In Benjamin Walker we lost one of those men of whom the country is justly proud, who especially represent the power of the nation: the so-called self-made men, who combine inborn talent with indomitable energy, dogged perseverance and determination, and ceaseless industry.

Other prominent names figure upon our death-roll of the past year, such as those of the Engineers Thomas Richardson and Richard Sennett, both well known in the naval world; Mr. Hugh Neilson, and Mr. Robert James Ransome of Ipswich; Mr. Richard Smith, who for so many years was the right hand of

Dr. Percy among his students in Jermyn Street; and two of our foreign members, M. Julien d'Andrimont of Liège, member of the Belgian Senate, and the Baron de Gargan, associate of the De Wendels of Hayange.

The introductory address delivered by the late Duke of Devonshire to the members of the Institute is certainly not inferior in interest, and in value for purposes of reference, to the succession of important addresses delivered since then by those, eminent through their identification with the progress of iron and steel manufacture and of metallurgical science, who have in the past twenty-two years occupied our presidential chair. In that address the history of the development of iron manufacture is discussed in most interesting and comprehensive fashion, and statistical details are given, which, while they then illustrated the progress made in the output of pig iron in this and other countries, are instructive at the present time as illustrating the development—little foreseen in some directions—which the industry has since attained. The President, in referring to the most extraordinary mineral wealth of the United States, pointed out that although in 1867 the production of pig iron in America had risen to nearly 1,350,000 tons (of 2240 lbs.), the price of labour did not warrant the belief that there was any immediate prospect of the United States competing with the iron-producing countries of Europe in the open markets of the world.

A very interesting report upon the state of iron manufacture was presented by Sir Lowthian Bell to the British Association at its meeting in Dundee in 1867. A critical examination was made therein of the relative position of ourselves and of Continental nations, as iron manufacturers, *à propos* of the Paris International Exhibition of that year; but in the encouraging view which that eminent authority presented of our position at the period named, he was not led to make any reference to the prominence which the United States were beginning to assume among iron-producing countries. After the lapse of twelve years, however, the production of pig iron in the States had been doubled, while in another ten years it had reached a figure approximating to the average production in Great Britain during the past ten years.*

* Mr. Robert S. M'Cormick, Resident Commissioner for Great Britain for the Chicago Exhibition of 1893, in a paper recently communicated to the Society of Arts

Viewed from our present standpoint, the observations made by our first President in his opening address of 1867, regarding the development of the manufacture of steel, are very interesting. The Duke pointed out that, "owing to recent inventions and improvements, steel had acquired an importance greatly exceeding that which it previously possessed." After referring to the then prevalent views regarding the nature of steel, and to its production by the cementation process, the puddling and the mixing processes, and the partial decarbonisation of cast iron by blowing air into pig iron melted in a charcoal hearth, he dwelt upon the interest with which the development of the Bessemer process had been watched by the iron-making world, upon the *promise* "which that process afforded of furnishing a supply of steel suitable for many most important purposes upon a scale and at a price hitherto unknown," and upon the association of the names of Joseph Heath with the first employment of manganese in steel manufacture, and of Robert Mushet with the important part played by manganese-alloys in the development of the Bessemer process. While the approaching expiration of the first Bessemer patent was referred to as likely to tend to an increase in the demand for its products, the limits which the then existing knowledge placed upon the application of the process were pointed out, and the advantages of the puddling process dwelt upon. It is interesting to note that, at any rate in Germany, these advantages have not yet been dispelled, in spite of the great revolution which the Bessemer and open-hearth processes have effected in the applications of wrought iron and steel. On the other hand, the importance which steel had acquired through the practical development of the Bessemer process, at the date of our first President's address, was but an indication of the new era upon which the iron and steel industries were about to enter. In that year the produce of Bessemer steel in the United Kingdom was only 160,000 tons, while open-hearth steel was not yet a staple product; in 1890 the

upon the future trade-relations between Great Britain and the United States, gives the following figures as demonstrating that the British iron and steel industry has been outstripped in magnitude by that of the United States. In 1890 the produce of pig iron in America was 9,202,703 tons against 7,875,130 tons in the United Kingdom; of manufactured iron, including rails, 2,820,377 tons were produced in America against 1,923,221 tons in Great Britain, and of Bessemer steel, 3,688,871 tons were American produce, while the production in the United Kingdom amounted to 2,014,843 tons.

British production of Bessemer steel exceeded two millions of tons, while that of open-hearth steel exceeded 1·5 millions of tons.*

A statement made in the Duke's address of 1869, that, so far as existing knowledge went, the Bessemer process was of limited application, as only certain kinds of iron were susceptible of successful treatment by it, affords, by a comparison with the present condition of things, an interesting illustration of the continuous progress made in the successful application of advances in scientific knowledge to practical purposes. The success which crowned the efforts of Thomas and Gilchrist, Snelus, and others to render the Bessemer and open-hearth processes efficient in their application to ores, the successful treatment of which by them appeared well-nigh hopeless in the earlier days of the Iron and Steel Institute's existence, has recently been very prominently before the public, and the members will certainly receive with special interest the communication which the Director of Naval Construction has promised us on experiments with basic steel.

In the discussion which took place at the meeting of the Institute of Naval Architects last year, *à propos* to a paper by M. J. Barba on recent improvements in armour plates, it became evident that the public were far better instructed as to progress made in such directions as this by other nations than as to advances made by ourselves; such information as Mr. White feels warranted in affording us with respect to our progress in practical experience on the merits of basic steel as applied to shipbuilding and other naval purposes will therefore be very welcome.

From the United States, interesting accounts have reached us of a continuation of the experiments with armour plates, 10½ inches thick, which were commenced at Annapolis in September 1890, when an all-steel and a nickel-steel plate, from the Creusot works, were tested in comparison with a compound plate of Cammel's make. Of these, the nickel-steel plate was considered to have shown itself somewhat superior to the all-steel plate, and very decidedly superior to the compound plate; and it is stated

* 1891 appears to have witnessed a very remarkable falling off in the production of Bessemer steel, to the extent indeed of about 35 per cent., while the production of open-hearth steel exhibits a reduction in the past year of only 3 per cent.

that Congress showed its appreciation of the importance of this result by appropriating a million dollars to the purchase of nickel ore. The second and third series of trials have been carried out at the Naval Ordnance Proof Ground at Indian Island near Washington. The plates fired at in October last, constituting the second series of three, are described as a high carbon nickel-steel plate from the Bethlehem Iron Company, one of low carbon nickel-steel from Carnegie, Phipps, & Co.'s works at Pittsburg, and a so-called "Harveyised" plate of low carbon steel from the Bethlehem Works. The description given of the Harveyising process identifies it as being a case-hardening or partial cementation treatment, the surfaces of the steel plate being hardened by carbonisation (and by a supplementary chilling process), and the increase in carbon dying away towards the interior of the mass. In the trials of these plates, that of high carbon nickel-steel appears to have stood the best, but the effect of the Harveyising process upon the powers of resistance of the low carbon steel plate seems to have afforded indications of beneficial effect such as to warrant the application of the process to nickel-steel plates included in the third series, fired at last November, and which comprised a high carbon nickel-steel plate from Carnegie, Phipps, & Co., a low carbon Harveyised nickel-steel plate from the same makers, and a high carbon Harveyised nickel-steel plate from the Bethlehem Company. In all the nickel-steel plates, including that from Creusot tried in 1890, the amount of nickel in the metal appears to have been a little above 3 per cent.

Care seems to have been taken to render all conditions attending the trials as uniform as practicable, with this not unimportant difference, that very much less time was allowed to elapse, in the second and third trials, between the firing of the successive rounds than in the first experiments.

A careful consideration of the results led the Board, of which Admiral Kimberley was President, to the unanimous conclusion that the high carbon Harveyised nickel-steel plate was the best, but that one part of the plate was much superior in resisting powers to the other, which was ascribable apparently to a want of uniformity in the Harveyising or carbonising treatment. The official report is also said to have recorded the unanimous opinion of the Board that both the high carbon nickel-steel Harveyised plate

and the high carbon nickel-steel untreated plate were superior to the Creusot nickel-steel plate tried in 1890.

Further trials will shortly be made of high and low carbon nickel-steel Harveyised plates, to be supplied by Carnegie, Phipps, and Co. From published analyses it appears that the high carbon nickel-steel plate manufactured by that Company, contained 0.45 per cent. of carbon and 0.65 per cent. of manganese, and the low carbon plates of nickel-steel, 0.26 per cent. of carbon and 0.75 per cent. of manganese.

The *New York Sun*, with what appears, from the reported results, to be very justifiable sentiments of pride, winds up an account of the results arrived at with the remark, that they show that America now stands at the top in the excellence of her ship-armour; and certainly our friends of the Bethlehem and Pittsburg Steelworks are to be warmly congratulated upon their achievements in this new direction.

Although the trials in the United States seemed to establish a marked superiority of nickel-steel plates over the compound plates of J. Brown & Co.'s manufacture, it is interesting to notice that this eminent firm is gallantly striving to maintain the high position which exhaustive trials had secured to that form of plate, as efficient armouring for ships of war, and that recent trials at Shoeburyness and at Portsmouth of experimental compound plates which have been submitted to a supplemental process devised by Captain Tressider, late Royal Engineers, seem, so far as I can learn, to have demonstrated that powers of resistance and endurance, much exceeding those of the compound plates tried in the United States and in the Ochta experiments of last year, can be secured to these structures. I have reason to hope that we shall receive a communication ere long on the interesting results which are being obtained in this direction.

My reference to the rapid advance which has been made in the United States in the manufacture of armour plates, will recall to the minds of many here present the memorable visit of the Institute to America in 1890; and here I cannot refrain from expressing the sorrow, shared, I am sure, by all members of the Institute, with which I have just learned of the death of Mr. William P. Shinn, so distinguished for his eminent services to

the United States in connection with railway traffic management, and with steel manufacture, and to whom those of us who visited the States were so deeply indebted for his zealous devotion to their best interests.

The valuable record of that visit, presented to us a few months ago by the American Institute of Mining Engineers, in the form of a portly volume, embracing full accounts of the proceedings and the papers read and discussed at the international meetings at New York and Pittsburg, constitutes an important work of reference, as well as an interesting memento of one of the most notable events in the history of our Institute. And now, thanks mainly to the self-sacrificing exertions of our much esteemed past President, Sir Lowthian Bell, we have been able to match this American volume with a companion work, the interest and value of which it would, I venture to say, be difficult to over-estimate. The series of monographs by Sir Lowthian Bell and other highly competent authorities which are embraced in this special volume (aptly named "The Iron and Steel Institute in America"), will certainly receive careful study—productive both of profit and of pleasure, at the hands not only of members of the Institute, but also of our trans-atlantic friends who so cordially received us; and our warmest thanks are due to the joint authors of this work, and especially to Sir Lowthian Bell, who, besides contributing some of the most valuable of its contents, undertook the arduous task of editing the volume; and I beg leave heartily to congratulate him upon the realisation of his wish, that the completed work should make its first appearance in public at this meeting.

An interesting illustration afforded by the inaugural address of the Duke of Devonshire in 1869 of the advance made in the knowledge at the disposal of the iron and steel maker, is found in his observations on the relations of carbon to iron and steel, a subject which I had occasion to discuss in some detail in my opening address last year, in reference to the then recent interesting investigations in that direction; a subject on which we may still hope to have further light thrown by the continued researches of Osmond and others. The very complete and systematic manner in which existing knowledge on this subject is treated in the first part, recently published, of Dr. Hermann

Wedding's new edition of his *Handbuch der Eisenhüttenkunde*, calls for the highest commendation.

The importance of pursuing the investigation of problems such as the conditions most favourable to economy in the use of fuel in the blast furnace, and conditions to be fulfilled in the form and dimensions of the furnace for ensuring efficiency and economy of working, were dwelt upon by the Duke of Devonshire in his comprehensive address, and reference was made to the elaborate inquiry into the chemical operations occurring in the blast furnace upon which Sir Lowthian Bell had then for some time been engaged. The interesting results arrived at by him, and the instructive discussions to which they and the conclusions based upon them gave rise, are memorable illustrations of the progress in the application of scientific research and reasoning to the study of metallurgic operations, in the promotion of which the Iron and Steel Institute has of late years played an important part, and the most recent outcome of which, in connection with the production of pig iron, is to be found in the remarkable achievements recounted by Mr. Gayley in his paper on the development of American blast furnaces, which was one of the most noteworthy communications dealt with at the New York meeting in 1890.

In directing attention to that paper in my address a year ago, I spoke of the reference made by Mr. Gayley to the importance of the elaborate series of investigations carried out, nearly a quarter of a century ago, by Sir Lowthian Bell on the chemistry of the blast furnace. I have had occasion since then to refresh my memory with regard to the ground covered by the work which our ex-President then carried out, and I must freely confess that I had no recollection of its extent nor of the mass of interesting and important experimental data accumulated by him, until I lately referred to the comprehensive and systematic investigations on the chemical phenomena of iron-smelting, which he communicated in detail to the meeting of the Institute at Merthyr in 1870. His paper on the chemistry of the blast furnace, to which I had the pleasure of listening at the Chemical Society in 1869, deals with the circumstances and conditions attending the union of iron with carbon in the blast furnace, and gives interesting results bearing upon the question of the temperature at which carbon is deposited

in a finely-divided state in ironstone when it is exposed to the waste gases, rich in carbonic oxide, of the blast furnace, and the subject is discussed more definitely, by the light of additional experimental information, in Sir Lowthian Bell's admirable work on the "Principles of the Manufacture of Iron and Steel," published in 1884. He there demonstrates the readiness with which carbon is deposited in iron sponge from carbonic oxide at temperatures up to a dull red heat; examines into the question whether the presence of iron in the metallic state in iron ore is indispensable for determining the dissociation of carbonic oxide, and, after concluding in the negative, and demonstrating that metallic iron is not more active in this respect than its oxide, he refers to trials made by him of the power of several other metals and metallic oxides to effect the dissociation of carbonic oxide.

In the researches communicated in 1870 to the Merthyr meeting, the whole of these experiments are given and discussed, and it is to be regretted that the interesting results arrived at did not receive greater publicity than they met with in the Transactions of a young technical Institute, then comparatively unknown in the scientific world, and in which the results of original scientific research would scarcely be sought for.

Without venturing to enter into the details of these researches, I may mention that experimental evidence favoured the conclusion that the carbon-impregnation of an iron ore by dissociation of carbonic oxide takes place at as low a temperature as de-oxidation, which, in the case of Cleveland ore, occurs at 200° to 210° C. (392° to 410° F.), and that freshly reduced spongy iron, at about that temperature, reduces carbon from carbonic oxide to an extent corresponding to 20–24 per cent. of its weight, but that, as the temperature approaches a red heat, the deposition of carbon diminishes considerably in amount.

The results of many experiments with other metals and their oxides showed that zinc, tin, chromium, and silicon, and their oxides are neither reduced by carbonic oxide at a temperature of about 420° (that of melted zinc), nor give rise to deposition of carbon; that copper and lead are reduced at temperatures up to a red heat, without deposition of carbon; that the higher manganese oxides are reduced to protoxide below a red heat without impregnation by carbon; but that nickel, and in a smaller degree

cobalt, suffer reduction from their oxides, with deposition of carbon.

Sir Lowthian Bell, while conducting his experiments at temperatures considerably below those prevailing at the particular positions in the blast furnace where the production of pig iron was believed to be effected, did not have recourse to so low a temperature as that at which Messrs. Mond, Langer, and Quincke, after having demonstrated (what appeared, in the absence of an acquaintance with Bell's results, a novel observation) that carbon was separated from carbonic oxide by passing the gas over nickel at a high temperature, found that this metal actually entered into the composition of the gas. Thus they started from the point, in this particular direction, up to which Sir Lowthian Bell had carried his observations twenty years previously, and obtained the remarkable nickel-carbon-oxide compound referred to by me in my address last year, which they have since succeeded in producing upon so considerable a scale as to afford prospect of its acquiring industrial importance.

In the description of their earliest results, they stated that attempts to produce similar combinations of carbon oxide with other metals, including iron, had failed. By persevering with research in many very varied directions, and especially with iron, they at length succeeded in volatilising notable, although small, quantities of the latter metal in a current of carbonic oxide, by using the finely-divided pure iron obtained by reducing the oxalate in a current of hydrogen at the lowest possible temperature (about 400° C.), by allowing the product to cool in hydrogen to 80° , and then by passing a current of carbonic oxide over the spongy metal. The gas, after this treatment, was found to impart a yellow colour to a colourless flame, and if conducted through glass tubes heated to between 200° and 350° C., it deposited a metallic mirror; at a higher temperature it furnished black flakes, which analysis showed to contain 79.30 per cent. of carbon. The quantity of iron- and carbon-oxide compound produced in this way was very small; by passing $2\frac{1}{2}$ litres of carbonic oxide per hour over the metal (the latter being from time to time reheated in a current of hydrogen), the issuing gas contained not more than 0.01 grm. of iron, equal to less than 2 c.c. of the gaseous iron compound in a litre of the carbonic oxide.

The gas-mixture, when passed through benzine or heavy mineral- or tar-oils, was partially deprived of the iron compound, and the result of examination of solutions of this kind led to the conclusion that the gaseous iron combination, analogous in composition to the nickel-carbon-oxide compound (or nickel-tetra carbonyl), had been found, and that its formula was $\text{Fe}(\text{CO})_4$.

In continuing their researches, Mr. Mond and Dr. Langer have succeeded in obtaining the iron compound in the form of a liquid of spec. grav. 1.4664 (at 18°C .), which distils without decomposition at 102.8°C ., and solidifies below 21° into yellow needle-shaped crystals. It is slowly decomposed by exposure to air, and when its vapour is heated to 180° , it is completely decomposed into iron and carbonic oxide. Analysis and the determination of its vapour density show the composition of the liquid to be represented by the formula $\text{Fe}(\text{CO})_5$, and Messrs. Mond and Langer have therefore called the compound *ferro-penta carbonyl*.

If exposed to light in a sealed vessel for several hours, it deposits gold-coloured tabular crystals having a metallic lustre like gold when dry, but becoming brown by gradual decomposition when exposed to air. These crystals appear to contain a slightly smaller amount of carbonic oxide than the liquid compound from which they are deposited. Mr. Mond and his collaborators are still actively engaged in pursuing the researches which have brought to light the formation of these remarkable metallic compounds, whose discovery and properties suggest possibilities in several directions of technical chemistry which will doubtless lead to interesting investigations.

The first report made by Professor Roberts-Austen to the Alloys Research Committee of the Institution of Mechanical Engineers, bearing upon the particular investigation undertaken by him at their request, although little more than introductory in its character, is full of interest, and of importance not only on account of the valuable information it furnishes regarding the method of investigation adopted by him and of the preliminary results attained by its agency, but also because of the interesting discussion elicited by its presentation to the Institution of Mechanical Engineers at their meeting last autumn.

At our annual gathering a year ago we had the advantage of receiving from Professor Roberts-Austen a description of the autographic method adopted by him for recording the results indicated by the Le Chatelier pyrometer, the efficient operation of which I had an opportunity of witnessing as a member of the Alloys Research Committee. We also heard from Sir Lowthian Bell that he had already successfully and very usefully applied this pyrometer to determine the temperature of the blast entering a furnace at a considerable distance from the point of observation. We shall, I trust, have the advantage of learning the results of further experience by Sir Lowthian and others in the practical application of this much-needed instrument in conjunction with the automatic recording system used by Professor Roberts-Austen; the observations made by the present President of the Institution of Mechanical Engineers, by Mr. Henry M. Howe of Boston, and by others at the discussion of the Professor's report, demonstrated that several valuable applications were already being made of the Le Chatelier pyrometer and the system of continuous record of its indications. While it is satisfactory to me, as one of the earliest to use the ingenious pyrometer designed by my distinguished friend the late Sir William Siemens, to note that its trustworthiness as an indicator of temperatures up to 500° C. has been vindicated by the work of Messrs. Callendar and Smith, the accuracy and sharpness of the indications of Le Chatelier's pyrometer, the simplicity of its character, and the well-established trustworthiness of its results at temperatures of over 1000° C., render it decidedly more valuable to the practical metallurgist, as well as to the scientific investigator, than any instrument of the class hitherto available. We shall none the less be glad to hear what Mr. Callendar has to tell us on the present occasion with regard to the results of his persevering and, I believe, successful labours in discovering and eliminating the defects of construction which served to destroy the confidence placed, in the first instance, on the indications afforded by platinum pyrometers.

The tendency of the discussion following the reading of Professor Roberts-Austen's report, which was shared in by Mr. Robert Hadfield, Mr. Henry M. Howe, and by some others whose right to criticism was beyond dispute, was to emphasise the

necessity for caution in the application of theoretical views, regarding the laws which regulate the mechanical or physical properties of metals, to predictions as to the influence upon the properties of metals, such as iron, of particular impurities. I believe no one will be disposed to differ from the view expressed on that occasion by Professor Arnold, that, for a thoroughly comprehensive examination into "the effects of small admixtures of certain elements on the mechanical and physical properties of iron, copper, lead, and other metals," it is indispensable to combine different lines of investigation with the particular one which Professor Roberts-Austen has so far prosecuted with very promising results.

The fame which Mr. Gruson has acquired in connection with the production of chilled iron structures, for land defence, presenting marvellous powers of resistance, must cause members of the Institute to look forward with much interest to the communication which has been promised us by the Director of the Gruson Works, Mr. E. Reimers, on the manufacture and application of chilled cast iron, a subject with which, especially in regard to the selection of varieties and mixtures of iron suitable for securing a structure of metal essential to the attainment of combined toughness and hardness in armour-piercing projectiles, I was much concerned in the days of my greatly lamented friend the late Sir William Palliser.

Another subject to which I devoted considerable attention twenty-three years ago, in co-operation with the late Dr. Matthiessen, bears directly upon some very interesting results which will be brought to your notice by my old and valued friend Colonel Dyer, of the Elswick Ordnance Works. In 1863 Dr. Matthiessen communicated to the British Association the results of some interesting researches into the chemical nature of alloys, which he followed up in 1866 with a preliminary report on the chemical nature of cast iron. In this memoir, after drawing a comparison between the physical deportment of what he terms the alloys of carbon and iron, and those of such alloys as are produced by copper with zinc and with tin, he discusses in some detail the question whether carbon exists in combination with iron, in cast iron, and expresses himself in favour of the view

that white iron is not actually a chemical combination of carbon with the metal, but rather a solidified solution in it of carbon, while grey iron is a solidified solution of the same kind, with carbon mechanically intermixed. But, while he supports this hypothesis by certain analogies between the specific electric conducting power of different varieties of iron and of alloys of other metals, he proposes to test the validity of his views by preparing pure iron, alloying it with various proportions of carbon, examining the physical and chemical properties of these alloys, and afterwards investigating the properties of alloys of the pure metal with various other metals and non-metals. Matthiessen's persevering endeavours to elaborate a process for the preparation of pure iron, which extended over three years, were at length crowned with success, and in 1869 I was engaged with him upon experiments with metal, obtained in the form of sponge, containing as its only impurity a minute trace of sulphur. This iron was prepared by fusing together perfectly pure and dried ferrous sulphate and sodium sulphate, completely washing the crystalline oxide thus obtained, and then reducing it to metallic sponge by heating it in thoroughly purified hydrogen. The spongy metal was welded together in the cold by powerful compression, for certain experiments; for others it was fused in very carefully prepared lime-crucibles. The experiments which it was hoped to undertake with this pure material, in the directions I have indicated, were arrested almost at their commencement by Dr. Matthiessen's death, and by the all-engrossing nature of my official labours. The process, which was elaborated with such trouble, may perhaps prove useful in connection with the investigation which Professor Roberts-Austen has undertaken for the Alloys Research-Committee of the Institution of Mechanical Engineers, but it appears to me that there is good prospect of procuring iron sufficiently pure, at any rate for certain of the experiments (when carried out upon a practical scale) which will form part of those investigations, by the very simple mode of procedure which Colonel Dyer has adopted in the production of iron containing only traces of carbon and silicon, no phosphorus, and less than two-hundredths of one per cent. of sulphur, and which affords a very interesting instance of the application of the basic furnace.

In concluding these few observations, I cannot forbear once more referring to the interesting address delivered to the members by our first President twenty-three years ago, in order to point out how strikingly its peroration illustrates the progress which has been made in the development of the steel industry during the past twenty-two years. While forcibly dwelling upon "the extraordinary influence which the manufacture of iron had come to exercise on the condition of society throughout the civilised world," the writer gives no indication of the part then played, or destined to be played, by *steel* in that civilising influence. Even seven years later, when steel manufacture had advanced with rapid strides, there was still great hesitation in adopting it for some of the most important purposes to which iron was applied; thus, Sir Nathaniel Barnaby wrote, at that time, "Our distrust of steel is so great that the material may be said to be altogether unused by private shipbuilders." Yet, a few years afterwards, it had come to pass that the examples of the marvellous development in the applications of iron, to which the Duke referred in illustration of his statements, constituted the very directions in which the steel manufacturer has accomplished his most prominent achievements, and in which the use of iron is becoming a memory of the past.

Sir BERNHARD SAMUELSON, Bart., M.P., was sure that he should be only giving expression to the general feeling of the members in moving a vote of thanks to the President for his interesting and valuable address. This was the second occasion on which they had been favoured with an address from an authority standing in so high a position scientifically as the President. He was sure that the subjects referred to in the address would give rise to reflections in the minds of the members which, not only from a scientific, but also from a practical point of view, would lead to important results. In the form of his address the President had adopted the plan, in the first place, of comparing the state of their present knowledge with that of the time when their lamented first President addressed the Institute, then consisting

of a comparatively small number of members, but he had also taken the opportunity of furnishing an index or a preface, as it might more properly be called, to the papers which were to form the interesting subjects of discussion at the present meeting. He felt sure that in both these respects the address they had heard would commend itself to the approval of the members. The terms of the resolution, which he was sure they would all most cordially adopt, were as follows :—"That the best thanks of the meeting be, and are hereby, offered to the President for his interesting and valuable address."

Mr. ANDREW CARNEGIE said that no more pleasant duty could be assigned to him than to second the proposal that had just been moved by his friend, Sir Bernhard Samuelson. It had been intimated to him, that in seconding the motion he might take the opportunity of referring to two of the points embraced in the President's address upon which they would be naturally anxious to hear something. He referred, of course, to the basic steel process, and to armour. Before entering upon either, he might be permitted to say with what interest he had observed the ceremony of the bestowal of that most cherished of all prizes connected with iron and steel—the Bessemer medal. He rejoiced that Mr. Cooper had been so highly honoured. He would tell him that his numerous friends in America, who would hear of it in the morning, would be glad to learn that the greatest honour which he could possibly receive in his profession had been conferred on him. He had reached the highest point possible for any man connected with that Institute, both in regard to the high order of service which obtained the prize, and on account of the man who gave it. It was a gift received direct from the king—the king of steel. His (Mr. Carnegie's) firm had fourteen open-hearth furnaces running constantly upon basic steel. He was not competent to criticise, from a scientific standpoint, the paper which Mr. White was to read, which he had had an opportunity of glancing through that morning; but he wished to say that an exhaustive series of tests just undertaken by the Pennsylvania Railway, the largest of their railway systems, conducted by its own people, had not only placed basic steel alongside of acid steel for boilers and fire-boxes, but

he had been informed that the question was being seriously entertained whether they would not specify that nothing but basic steel should be used for those purposes. He hoped to be able to furnish the Institute with a copy of the remarkable results which the Pennsylvania Railway authorities had obtained. He was speaking there simply for the purpose of giving information: he had no more interest in making basic than in making Bessemer—his firm made both—but he only mentioned it as a note of progress.

He thought that he must attribute the President's altogether too complimentary remarks with regard to armour to his generous nature, which was more than willing to give due credit to manufacturers in other parts of the world. He considered that so far as the United States had proceeded in armour, it was merely experimental. They had not made enough of the material. So far it was true that they thought the admixture of the nickel in certain proportions did give one quality to the steel, viz., tenacity, so that shots passing through it did not crack it, but were held in. With regard to Harvey's system, they had Harveyised a few plates, but the result was a matter to be decided in the future. They had gone to this extent in America: A few experimental plates had been made; and, while one part of the plate had shown extraordinary results, the other part of the plate had not. He therefore wished to disclaim for America extraordinary credit for anything it had yet done in armour-plates. What it might do, the future would tell.

On behalf of all Americans connected with iron and steel, he wished to thank the President for the kind reference and sympathetic words he had used with regard to the death of his friend, Mr. Shinn. It was his privilege to secure Mr. Shinn's services, and associate him with his Company, very early in its career, indeed when they began the manufacture of steel. It was one of the pains of mature life that one could hardly open a newspaper without finding that another, and another, and another of our cherished associates had passed away. The President's reference to Mr. Shinn would greatly gratify his family and friends, for he knew that, of the many compliments received by Mr. Shinn, none were more highly valued than those which that Institute and its members showered upon him. He thought that that was another illustration

of the fact that the two branches of the English-speaking race, instead of drifting apart, were drawing closer together—they were rapidly becoming interlaced, even in their friendships.

It had been his privilege to pass, during the last two months, from the Pacific Coast to New York, 3000 miles, in a special car, a moving hotel, and also to pass from New York to Liverpool, an equal distance by sea, in another moving hotel; and there was no comparison as to the comfort and the ease with which the journey over sea had been accomplished compared with that over land, even under the most favourable conditions. He had therefore been speculating on this point, that the sea, which had hitherto been considered a barrier between the countries, was by the triumph of science to become the easiest mode of communication. They knew that, if the territory of Britain and America adjoined, there would be but one flag and one government. Then, if the sea was to be a good substitute for the land, as he believed it would, what was to prevent the two countries becoming one. A member asked which? That reminded him of what a man said to him in business, "Well, you know, Carnegie, you and I will have no dispute; you and I are one." "Yes," he had replied, "that is true; but which one?" Although that remark had been interposed, it was not necessary to ask which one. When the two branches of the English-speaking races consolidated, there was enough for two. It would be the triumph, neither of one nor the other, but a union of two equals in the holy bonds of marriage—they would no longer be twain, but one flesh—as Scotland and England are one, so he hoped that one day a federation of the English-speaking people, wherever found, would weld them all in a common citizenship.

The PRESIDENT said he was very grateful for the flattering way in which his remarks had been received. He was glad that they had been the means of drawing forth the interesting observations to which the members had just listened from Mr. Carnegie, who came among them too rarely. They were always glad to see him taking part in their meetings, as one of themselves—as a member of the Council of whom they were all proud.

EXPERIMENTS WITH BASIC STEEL.

By W. H. WHITE, C.B., F.R.S.,

DIRECTOR OF NAVAL CONSTRUCTION AND ASSISTANT CONTROLLER, ROYAL NAVY.

IN this paper it is proposed to summarise the results of an experimental inquiry into the qualities of steel, of shipbuilding quality, made by the basic process, which inquiry has been conducted by officers of the Admiralty during the last six years.

The subject is one of considerable interest and importance to both the makers and users of mild steel, and it seemed desirable that the statement I have to make should be submitted to the Iron and Steel Institute, rather than to any other technical association.

It is well known that, about seven years ago, steel made by the basic process was used to a certain extent in mercantile shipbuilding, and subsequently ceased to be employed. At that time I was not in the public service, being engaged in the conduct of a large private shipbuilding establishment on the Tyne. Consequently, I was personally familiar with this first chapter in the history of basic steel as applied to ship-construction. It would be out of place to enter into any details here, nor is it necessary to do so. At the same time it has an important bearing on action subsequently taken by the Admiralty, and is therefore mentioned.

In March 1886 Mr. Percy Gilchrist made an official application to the Admiralty on behalf of makers of steel using the basic process for a searching investigation into the qualities of that material. It was my duty, as Director of Naval Construction, to advise their Lordships on this matter. With a full knowledge of what had happened in mercantile practice, I recommended compliance with the request, and no time was lost in prosecuting the inquiry.

This decision of the Admiralty was in complete accordance with its recognised policy of enlarging, as much as possible, the

sources of supply for shipbuilding materials. Further, it was recognised that the encouragement of the basic process was a matter of national importance, since that process, if successful, made British steel-makers much less dependent on supplies of foreign non-phosphoric ores, and enabled native phosphoric ores to be utilised.

Six firms granted facilities to Admiralty officers to visit their works, and to select freely samples of basic steel for purposes of testing. These samples, for the most part, were taken from plates which were being rolled in execution of current orders; they were not specially manufactured to comply with the Admiralty specification for steel of shipbuilding quality, except in a few instances. Consequently there were considerable differences in the strength and ductility of various samples, and the range of the experiments was very great. The materials tested included specimens of both open-hearth and Bessemer manufacture.

In July 1887 I read before the Institution of Naval Architects a paper "On some Recent Experiments with Basic Steel," in which the details of the experiments are given. To the *Transactions* of that Institution I must refer those who desire to obtain complete information; and in the same volume they will find a valuable paper by Mr. Martell, the Chief Surveyor of Lloyd's Register, giving the results of an extensive series of tests which he had conducted on basic steel, with special reference to mercantile shipbuilding.

The experiments of 1886-7 constituted a most searching preliminary investigation into the qualities of basic steel, when subjected to tensile, bending, and percussive strains; when welded, punched, sheared, annealed, heated, and reheated; and when subjected to rough usage and hard work, inevitable to the processes of shipbuilding. Writing in 1887 I said, "The experimental inquiry has been as thorough as, if not more thorough than, that which preceded the adoption of mild (acid) steel by the Admiralty in 1875. As a whole, the results of the investigation have been very satisfactory, affording good evidence of the trustworthiness of basic steel. The only extension which suggests itself as desirable in this series of experiments, is in the direction of tests of *riveted* work."

One other statement should be made. At the outset basic 1892.—i.

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steel-makers endeavoured to induce us to lower the Admiralty standard of *minimum* tensile strength from 26 tons per square inch to 23 or 24 tons. This concession could not be made. No doubt it would have simplified the problem to be dealt with by the steel makers. On the other hand, it is a necessity for warships, built on comparatively light scantlings, that, for the maintenance of both strength and stiffness, the minimum tensile strength above mentioned shall be maintained.

Moreover it speedily appeared that basic steel makers were under-estimating what their process could accomplish; and that not merely could Admiralty conditions for shipbuilding steel be met, but that satisfactory basic steel could be produced in which ultimate tensile strengths of 32 to 36 tons per square inch could be associated with good ductility and working qualities.

Having obtained these satisfactory experimental results, the Admiralty placed, in 1887, a small trial order for basic steel plates and bars, which were used in some of the less important portions of ships building at Chatham, and were favourably reported on. It was then decided provisionally to place basic steel on the same footing as Bessemer acid steel, the use of the latter material in Admiralty practice being limited to the less important portions of ships' structures. Further, it was arranged to proceed with tests of basic steel in the form of *riveted* samples, as soon as might be convenient.

In conversation with steel-makers I have often been asked why we attach so much importance to tests of *riveted* samples, and why we are not content with the tensile, bending, and quenching tests which are made at the works. It may be convenient, therefore, to explain briefly.

Fifteen or sixteen years ago, when I was conducting, at Pembroke, a series of experiments on acid steel made by the Bessemer and open-hearth processes—I being at the time an assistant to my friend Sir N. Barnaby (late Director of Naval Construction)—it was discovered that the preparation for, and performance of, the process of riveting constituted a crucial test. Specimens of Bessemer steel proved equal to specimens of open-hearth steel in tensile, percussive, and forge tests, in capacity for welding, and in the loss of strength consequent on punching. But, when riveted samples were tested—the plates from which

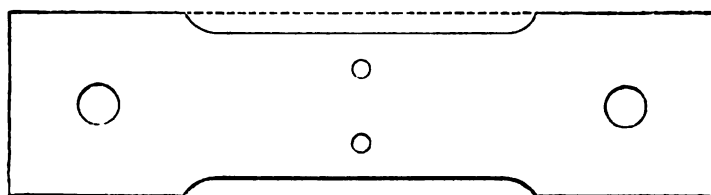
those samples were cut being the same that had been used in the previous series of experiments—the Bessemer acid steel proved inferior to, and much less trustworthy than, the open-hearth steel. Repeated experiments only confirmed this conclusion; and, consequently, it was decided in future Admiralty practice not to employ Bessemer acid steel in the more important parts of ships' structures, where severe tensile stresses have to be borne. This decision was not then announced in set terms. The Admiralty desired not to prejudice any mode of manufacture. In our specifications, however, power was always taken to order any portions of the material that might be selected of *open-hearth* manufacture.

Steel-makers appear to have overlooked the fact that the crucial character of riveted tests was fully explained in a paper on "The Use of Steel in Naval Construction," read by Sir Nathaniel Barnaby before this Institute in 1879. Again and again representations have been made to us that our insistence on the specification of open-hearth steel for certain classes of work was unreasonable, and triumphant reference has been made to comparative tests of sample strips—*non-riveted*—where converter steel has compared favourably with open-hearth. To all such persons I commend the reading of Sir N. Barnaby's paper, and can add that our later experience only confirms the conclusions therein recorded. With converter steel, riveted samples have given less average strength, greater variations in strength, and much more irregularity in modes of fracture than similar samples of open-hearth steel.

Resuming my narrative of Admiralty experiments, it must be stated that the first tests with riveted samples of Bessemer basic steel were made by our officers at the works of a private firm. The results are tabulated in Tables I. and II. In the former are the ordinary tensile tests of six unannealed samples cut from one "blow." The average ultimate tensile strength was 29·9 tons per square inch, and the elongation in eight inches 21·7 per cent. The tests of four annealed samples are also given. Table II. contains the results of tests on riveted samples, made from the same "blow." The majority of the experimental joints were made to represent fairly portions of the laps and butts of the bottom plating of a ship. In a few cases, the rivets were either

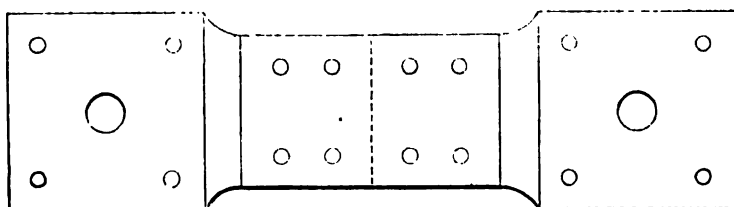
closely pitched or otherwise disposed, so that the plate should fracture before the rivets sheared. The rivets were of basic steel, and proved to have excellent working qualities, while their shearing strength was practically identical with that of rivets of equal size made of open-hearth acid steel. In the cases where

FIG. 1.



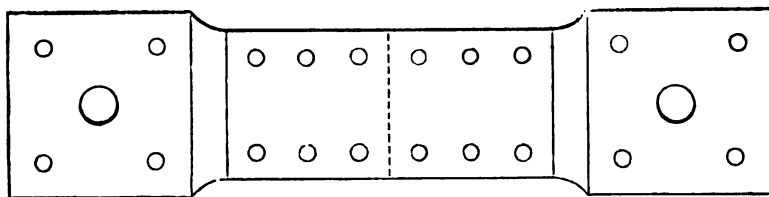
Dotted Lines show piece before shaping.
 Drawn Lines show piece after shaping.

FIG. 2.



Double-riveted Single Strapped Butt.

FIG. 3.



Treble-riveted Single Strapped Butt.

the plate fractured, the mean breaking stresses were respectively 23.6 tons per square inch for the close-pitched rivets, and 26.7 tons per square inch for the larger pitch. These figures have to be compared with 29.9 tons per square inch for the unpierced plate.

It is unnecessary to analyse the figures further, as they are

given chiefly because they represent the first tests made on basic riveted samples by Admiralty officers.

Tables III. and IV. contain the results of the earliest series of experiments on riveted samples of basic Bessemer steel, made at Pembroke in 1888. These experiments were conducted on exactly the same lines as those made in 1875-83 on acid steel, so that the results might be compared. Figs. 1, 2, 3 show the details of the samples used in testing the effects of punching and riveting. Notes on the Tables contain nearly all necessary explanations. Up to the stage of riveting, the basic Bessemer samples compared well with open-hearth acid samples previously tested. Turning to Table IV., however, much less satisfactory results are reached. Fracture occurred in a most irregular fashion, and at very low breaking stresses in many instances. No method of averages fairly represents such conditions, and the figures given speak for themselves. It may be added that, with open-hearth acid samples of $\frac{1}{2}$ -inch steel plates with $\frac{3}{4}$ -inch rivets and countersunk points, the breaking stress on the sectional area of the plate across a line of rivet-holes was found to be as great as that of an unperforated plate. It will be seen that, in the basic Bessemer samples of similar character, the breaking stress varied from equality to that of the unperforated plate, down to about 63 per cent. of the full strength.

These results were admittedly unsatisfactory, but practically no worse than had been obtained with acid Bessemer samples in some previous trials.

The representatives of the Bessemer basic manufacture considered that these limited trials were not conclusive, and their view was doubtless a reasonable one. At the same time it was thought preferable to give precedence to trials of open-hearth basic steel, before repeating trials on the Bessemer make. Owing to various causes, for which the Admiralty are not responsible, these trials of open-hearth basic steel have been long deferred—from the end of 1888 to the end of 1891. The further trials of basic Bessemer steel are now in progress, but the results cannot be given.

Tables V. and VI. contain the particulars of the first series of tests on riveted samples of open-hearth basic steel made at Pembroke in 1889. This was supplied by the same firm which had

furnished the basic Bessemer steel of which tests appear on Tables III. and IV.

The experiments were made on the same lines as in previous cases.

It will be seen from Table V. that the material supplied in its unperforated condition was below the minimum of tensile strength, viz. 26 tons per square inch, fixed by the Admiralty for ship work.

It stood punching and working well, and in most of the riveting tests it also gave better results than the basic samples which preceded.

On the other hand, there were cases in which the fracture of riveted samples was irregular, particularly with the pan-heads and snap-pointed rivets, which is a mode of fastening used only in the internal work of ships. For the bottom plating and all important portions of the structure, rivets with countersunk points are invariably used.

The results indicated a want of uniformity in the material, and led to a close investigation of the plates by representatives of the firm. Their opinion was that some of the plates had been injured in the process of annealing, and that consequently the tests were not a trustworthy guide to the quality of the material.

It has been preferred, however, to give the actual results of tests with this explanation, rather than to make a selection from the series of experiments. Such a selection might, of course, be unduly favourable to the process of manufacture.

Up to this point the Admiralty had purchased the material used in the Pembroke experiments; and, on the basis of the quotations sent in, all the material had been ordered from one firm.

Mr. Gilchrist now offered to supply, without charge to the Admiralty, materials made by several representative firms, so that the series of experiments might be continued on a larger scale. This offer was accepted in November 1889.

Much time was occupied in waiting for the material, and no unavoidable loss of time occurred on the part of the Admiralty in carrying out the further tests.

The results are given in Tables VII. to XIV., and represent tests on open-hearth basic steel made by four different firms.

In the case of each firm the series of tests was identical with that above described.

Tables VII. and VIII. give the particulars of the behaviour of samples made from material supplied by the same firm as had previously furnished open-hearth and Bessemer basic steel for the Pembroke experiments.

It will be seen from Table VII. that the tensile strength of this material was about the minimum admitted by the Admiralty for shipbuilding quality; that it stood the punching, &c., well; and, what is more important, in the riveting-tests the results were uniform and excellent.

These results appear to justify the opinion which had been given by the representatives of the firm as to the material tested in Tables V. and VI. having been accidentally damaged during manufacture.

The corresponding tests for samples of material supplied by another firm are given in Tables IX. and X. Here also the tensile strength of the unperforated plates is about at the lower limit admitted by the Admiralty, and the results of the riveting-test are excellent.

Tables XI. and XII. contain a still more interesting series of tests, seeing that they deal with material where the strength of the unperforated plates is actually above the 30 tons named as the upper limit in Admiralty specifications for ship quality. The ductility is good, the material stands punching, and the riveting-tests are remarkably good.

Still another series of tests, representing results obtained by a fourth firm, are given in Tables XIII. and XIV. Here the ultimate tensile strength is, as nearly as possible, the mean fixed by the Admiralty conditions for plates for ship work. The mean extension in 8 inches is 25.8 per cent. as against the 20 per cent. fixed in the Admiralty conditions. The material stands punching and working well, and the tests of riveted samples are entirely successful.

These later tests of material, supplied from different parts of the country, and by different makers, afford conclusive evidence that the basic process, applied by competent makers to the production of open-hearth steel, may be trusted to give us results no less satisfactory than those obtained with acid open-hearth steel.

The method of averages is, of course, open to question, as has been remarked above, but the following short summary is interesting.

With open-hearth acid steel of standard quality, a large series of experiments has given the following results:—

	Tons per Square Inch.
Tensile strength of plain strips	28.2
Tensile strength of strips $\frac{1}{2}$ an inch in thickness with $\frac{1}{8}$ -inch holes punched before shaping	22.1
Or a loss through punching of nearly 22 per cent.	

Taking that make of basic steel shown in Tables XIII. and XIV.,

Tensile strength of plain strips is	27.6
And that of strips of the dimensions and character named above	24.6
Showing a loss due to punching of about 11 per cent.	

The material of higher tensile strength, shown in Tables XI and XII,

has a normal strength of	31.3
The loss due to punching is only about 2 tons per square inch, or less than 7 per cent.	

With the milder qualities of basic steel there is practically no loss in punching, but these qualities are not so suitable for our requirements as the other two.

Turning to riveting, and without going into details, it may be said that, with the standard open-hearth acid plates, there is *no loss in ultimate tensile strength per square inch of sectional area* when rivets with countersunk points are used; and, for practical purposes, the same thing is true with basic open-hearth steel. In fact some of the tables show a gain in the riveted samples as compared with the unperforated strips.

With snap-pointed rivets, acid open-hearth steel loses about 12 to 13 per cent. as compared with unperforated samples. For similar tests of open-hearth basic steel there are in many instances no losses whatever. On the whole the basic specimens compared exceedingly well in all respects with those made by the acid process.

The shearing tests of the rivets made by the basic process are practically identical with those of rivets made by the acid process.

	Tons.
The single shear of a $\frac{3}{4}$ -inch rivet with countersunk point is, for the acid steel	11.6
And for the average of the basic steel	11.5
The double shear of a $\frac{3}{4}$ -inch rivet is with acid steel about	21.2
And with basic steel about	21.3

With these results before them, the Admiralty decided to admit basic steel made in the open-hearth on practically the same terms, as regards ship work, as those on which acid open-hearth steel has been admitted. The step has not been taken without the fullest investigation. In fact much more has been done in the way of preliminary testing of basic steel than was done with acid steel. The new process will, no doubt, have to be carefully watched, in order that uniformly good results may be obtained.

It may be said that the tests, of which an account has been given in this paper, while satisfactory, were made on material much of which was specially manufactured for the purpose.

This is perfectly true; but, on the other hand, if such satisfactory results can be obtained in sample orders, it is clearly only a question of management and precaution if similar results are to be obtained on a large scale.

Should the manufacturers of basic steel in the open-hearth succeed in obtaining a share of the Admiralty orders for ship-building purposes, it will be necessary for them to use every effort to secure, in the material supplied, qualities equal to those which have been proved to exist in the experimental samples.

Close watch will be kept upon the working of the material in the shipyards: and the Admiralty system provides for frequently making what are termed "casual tests" of the material in the dockyards, supplementing those made at the works of the manufacturers by the resident overseers.

In short, as users as well as buyers, the Admiralty can with safety enter upon the use of a material which has satisfactorily passed all preliminary tests, being assured that, should any deterioration in quality occur in the supplies as compared with the samples, the facts will be immediately ascertainable.

It will be noted that this paper has dealt exclusively with basic steel for shipbuilding purposes. It is our practice to gain experience of a new material for ship work before considering its adoption for boiler-making. This was done when acid mild steel was introduced, and the same course is still being followed. For boiler tubes, however, basic open-hearth steel is already admitted by the Admiralty.

TABLE I.—Experiments made in 1887 on Basic Bessemer Steel (*Sleeper Quality*).

Description of Steel.	Distinguishing No.	Plate.			Tensile Tests.				Remarks.
		Thickness before Testing.	Width before Testing.	Sectional Area before Testing.	Length-wise or Across.	Breaking Stress in Tons.			
						Actual Producing Rupture.	Per Square Inch of Area before Testing.	Extension in Eight Inches.	
Converter	Blow. 379	Ins. .39	Ins. 1.51	Sq. Ins. .588	L.	Tons. 17.9	Tons. 30.4	Per Cent. 21	...
Do.	379	.39	1.51	.588	A.	17.8	30.3	21	...
Do.	379	.495	1.51	.747	L.	23.1	30.9	19	...
Do.	379	.50	1.51	.755	A.	21.4	28.3	20	...
Do.	379	.50	1.51	.755	L.	21.8	28.9	23	...
Do.	379	.50	1.51	.755	A.	23.1	30.6	26	...
Cold forge and temper tests, rough shown, satisfactory.									
The following samples were tested after annealing:—									
Converter	379	.39	1.51	.588	L.	16.5	28.0	26	...
Do.	379	.385	1.51	.581	A.	16.3	28.1	16	...
Do.	379	.50	1.51	.755	L.	20.0	28.5	29	...
Do.	379	.50	1.51	.755	A.	21.3	28.2	25	...

TABLE II.—Experiments made in 1887 to Ascertain the Effect of Riveting on Basic Bessemer Steel (Sleeper Quality).

Description of Steel	Disintegrating Number.	Nature of Joint.	Plate.		Riveting.			Mode of Fracture.	Breaking Stress in Tons.			Temperature in Degrees Fahr.	Remarks.
			Thick-ness before Testing.	Width before Testing (Net).	Sectional Area before Testing (Net).	Nature.	Diameter of Rivet.	Pitch of Rivets.	Actual Fracturing Rupture.	Per Square Inch Of Area before Testing.	Mean Result.		
Converter	A ₁	Double riveted lapped joint with shorn edges.	1 1/2	4 1/2	2 1/2	Pan heads, counter-sunk points.	3/4	4 1/2	45.6	...	...	...	
Do.	A ₂	Do. with planed edges.	1 1/2	4 1/2	2 1/2	Do.	3/4	4 1/2	42.4	...	...	...	
	A ₃ B ₁	Single riveted, single strapped butt, with planed edges.	1 1/2	4 1/2	2 1/2	Do.	3/4	2	45.8	24.5	23.6	...	
Do.	B ₂ C ₁	Do.	1 1/2	...	1.54	Do.	3/4	2	37.8	...	...	...	
Do.	C ₂ D ₁	Double riveted, single strapped butt, with planed edges.	1 1/2	4 1/2	2 1/2	Do.	3/4	4 1/2	35.0	22.7	...	...	
	D ₂ E ₁	Treble riveted, single strapped butt, with planed edges.	1 1/2	4 1/2	2 1/2	Do.	3/4	4 1/2	25.6	...	...	...	
Do.	F ₁	Do.	1 1/2	...	2 1/2	Do.	3/4	4 1/2	45.5	...	...	...	
Do.	F ₂ F ₁	Treble riveted, single strapped butt, with diamond-shaped butt straps.	1 1/2	...	2.4	Do.	3/4	4 1/2	45.9	27.5	26.7	...	
	G ₁	Double riveted, double strapped butt with alternate rivets omitted in outside row.	1 1/2	...	...	Do.	3/4	3	66.1	26.0	...	...	
Do.	G ₂	Do.	1 1/2	...	...	Pan head, snap points.	3/4	3	62.4	...	...	...	Irregular fracture.
Do.		Do.	1 1/2	...	...	Do.	3/4	3	65.1	...	...	...	Irregular fracture.

TABLE III.—*Experiments made at Pembroke Dockyard in 1888, on Basic Bessemer Steel.*

Description of Steel.	Distinguishing No.	Plate.		Tensile Tests.				Temperature of Test, in Degrees Fahrenheit.	Remarks.
		Thickness before Testing.	Width before Testing (Net).	Sectional Area before Testing (Net).	Length-wise or Across.	Breaking Stress in Tons.			
						Actual Producing Rupture.	Per Square Inch of Area before Testing.		
Converter	1	Ina. .49	Ina. 2.09	Sq. Ins. 1.024	...	Tons. 27.9	Tons. 27.2	Per Cent. 29.5	60°
Do.	2	.49	2.11	1.033	...	27.2	26.4	32.0	60°
Do.	3	.49	2.07	1.014	...	29.2	28.8	28.7	60°
Do.	4	.49	2.0	.98	...	29.1	29.7	27.9	60°
Do.	5	.49	3.44	1.685	...	38.5	22.9	...	60°
Do.	6	.49	3.42	1.675	...	36.8	22.0	...	60°
Do.	7	.49	3.15	1.543	...	46.9	30.4	...	60°
Do.	8	.50	3.13	1.565	...	47.2	30.2	...	60°
Do.	9	.50	3.22	1.61	...	44.6	27.7	...	60°
Do.	10	.505	3.21	1.621	...	48.5	29.9	...	60°
Do.	13	.50	3.43	1.715	...	52.9	30.8	...	60°
Do.	14	.50	3.43	1.715	...	52.4	30.6	...	60°

Unperforated plate.

Holes punched $\frac{1}{2}$ -inch before shaping. See Fig. 1.Holes drilled $\frac{1}{2}$ -inch, countersunk right through plate. See Fig. 1.Holes punched $\frac{1}{2}$ -inch before shaping, countersunk to $\frac{1}{4}$ -inch. See Fig. 1.Holes drilled $\frac{1}{2}$ -inch. See Fig. 1.

TABLE IV.—Experiments made at Pembroke Dockyard in 1888, to Ascertain the Effect of Riveting on Basic Bessemer Steel.

Description of Steel.	Distinguishing Number.	Nature of Joint.	Plate.		Sectional Area before Testing (Net).	Riveting.			Mode of Fracture.	Breaking Stress in Tons.			Temperature of Test in Degrees Fahrenheit.	Remarks.
			Thick-ness before Testing.	Width before Testing (Net).		Nature.	Diam-eter of Rivet.	Pitch of Rivets.		Actual Produc- ing Rupture.	Per Square Inch. Of Area before Testing.	Mean Results.		
Converter	15	Double riveted, single strapped butt. See Fig. 2.	Ins. .5	Ins. 2.33	Sq. Ins. 1.165	Pan heads, countersunk points.	Ins. $\frac{3}{4}$	Diam. ...	Butt strap broke.	Tons. ...	Tons. 18.5	Tons. ...	70°	
Do.	16	Do.	.5	2.39	1.195	Do.	$\frac{3}{4}$	...	Plate broke.	35.6	29.8	...	70°	
Do.	17	Do.	.48	2.65	1.272	Pan heads, snap points.	$\frac{3}{4}$	...	Do.	27.8	21.9	...	70°	
Do.	18	Do.	.48	2.61	1.252	Do.	$\frac{3}{4}$	...	Butt strap broke.	...	15.7	...	70°	
Do.	19	Do.	.5	3.21	1.605	Pan heads, countersunk points.	1	...	Do.	...	25.7	...	70°	
Do.	20	Do.	.5	3.21	1.605	Do.	$\frac{1}{2}$	...	Do.	...	25.7	...	70°	
Do.	21	Do.	.5	3.49	1.745	Pan heads, snap points.	$\frac{1}{2}$	...	Do.	...	17.1	...	70°	
Do.	22	Do.	.5	3.49	1.745	Do.	$\frac{1}{2}$	...	Plate broke.	52.0	29.8	...	70°	
Do.	23	Treble riveted, single strapped butt. See Fig. 3.	.48	3.29	1.579	Do.	$\frac{3}{4}$	$3\frac{1}{2}$	Do.	28.7	18.2	19.6	70°	
Do.	24	Do.	.5	3.28	1.64	Do.	$\frac{3}{4}$	$3\frac{1}{2}$	Do.	34.4	21.0	...	70°	
Do.	25	Do.	.48	3.7	1.776	Do.	$\frac{3}{4}$	4	Do.	35.6	20.1	...	70°	
Do.	26	Do.	.48	3.68	1.766	Do.	$\frac{3}{4}$	4	Do.	27.8	15.7	...	70°	
Do.	27	Do.	.5	4.11	2.055	Do.	$\frac{3}{4}$	$4\frac{1}{2}$	Do.	31.9	15.5	...	70°	
Do.	28	Do.	.5	4.1	2.05	Do.	$\frac{3}{4}$	$4\frac{1}{2}$	Do.	34.8	17.0	...	70°	

TABLE V.—*Experiments made at Pembroke Dockyard in 1889, on Basic Open-Hearth Steel.*

Description of Steel.	Distinguishing No.	Plate.		Sectional Area before Testing (Net).	Tensile Tests.			Temperature of Test-house in Degrees Fahrenheit.	Remarks.
		Thickness before Testing.	Width before Testing (Net).		Length-wise or Across.	Breaking Stress in Tons.			
						Actual Producing Rupture.	Per Square Inch of Area before Testing.		
Open-Hearth Do.	1	Ins. .45	Ins. 1.98	Sq. Ins. .891	L.	Tons. 21.5	Tons. 24.1	Per Cent. 27.5	No. 2 broke outside centre marks.
	2	.45	1.98	.891	L.	21.5	24.1	...	Unperforated plate.
	3	.47	1.98	.931	A.	22.9	24.7	30.0	Holes punched $\frac{1}{4}$ -inch before shaping. See Fig. 1.
	4	.47	1.98	.931	A.	23.2	24.9	28.7	Holes punched $\frac{1}{4}$ -inch after shaping. See Fig. 1.
	5	.47	3.20	1.504	...	35.7	23.7	...	Holes drilled $\frac{1}{4}$ -inch and countersunk through. See Fig. 1.
	6	.47	3.20	1.504	...	32.8	21.8	...	Holes punched $\frac{1}{4}$ -inch and countersunk to $\frac{1}{4}$ -inch. See Fig. 1.
	7	.47	3.20	1.504	...	30.6	20.3	...	Holes drilled $\frac{1}{4}$ -inch. See Fig. 1.
	8	.47	3.20	1.504	...	31.7	21.1	...	
	9	.46	2.95	1.357	...	34.6	25.5	...	
	10	.46	2.95	1.357	...	37.2	27.4	...	
	11	.46	3.12	1.435	...	40.0	27.9	...	
	12	.45	3.12	1.404	...	32.4	23.1	...	
	13	.46	3.35	1.541	...	39.2	25.5	...	
	14	.46	3.35	1.541	...	41.2	26.7	...	

Note.—Test-pieces from No. 1 of Table V. to No. 22 of Table VI. (except Nos. 5, 6, 7, 8) were made from the same plate.

TABLE VI.—Experiments made at Pembroke Dockyard in 1889, to Ascertain the Effect of Riveting on Basic Open-Hearth Steel.

Description of Steel.	Distinguishing Number.	Nature of Joint.	Plate.		Riveting.		Mode of Fracture.	Breaking Stress in Tons.			Temperature of Test-house in Degrees Fahr.	Remarks.		
			Thick-ness before Testing.	Width before Testing (Net).	Sectional Area Testing (Net).	Nature.		Diameter of Rivet.	Pitch of Rivets.	Per Square Inch.				
										Actual Producing Rupture.			Of Area before Testing.	Mean Results.
Open-Hearth	15	Double riveted, single strapped butt. See Fig. 2.	.48	Ins. 2.45	Sq. Ins. 1.176	Pan heads, countersunk points.	Ins. $\frac{3}{4}$	Diam. ...	Tons 33.4	Tons. 28.4	Tons. 28.8	62°		
Do.	16	Do.	.48	2.45	1.176	Do.	$\frac{3}{4}$	...	34.5	29.3	27.1	62°		
Do.	17	Do.	.48	2.77	1.33	Pan heads, snap points.	$\frac{3}{4}$	...	36.6	27.5				
Do.	18	Do.	.48	2.77	1.33	Do.	$\frac{3}{4}$	...	35.6	26.8	...	62°	Irregular fracture.	
Do.	19	Do.	.47	3.07	1.44	Pan heads, countersunk points.	$\frac{3}{4}$	...						
Do.	20	Do.	.46	3.07	1.41	Do.	$\frac{1}{2}$	...	40.6	28.8	...	62°		
Do.	21	Do.	.46	3.37	1.55	Pan heads, snap points.	$\frac{1}{2}$	...	44.4	28.6	29.4	62°		
Do.	22	Do.	.46	3.37	1.55	Do.	$\frac{1}{2}$	...	46.8	30.2	24.1	62°	All plates punched, butt straps drilled.	
Do.	23	Treble riveted, single strapped butt. See Fig. 3.	.46	3.34	1.536	Do.	$\frac{1}{2}$	3½	34.0	22.2				
Do.	24	Do.	.46	3.34	1.536	Do.	$\frac{1}{2}$	3½	39.7	25.9	21.8	62°		
Do.	25	Do.	.46	3.78	1.74	Do.	$\frac{1}{2}$	4	38.7	22.2				
Do.	26	Do.	.46	3.78	1.74	Do.	$\frac{1}{2}$	4	37.3	21.4	16.9	62°		
Do.	27	Do.	.46	4.15	1.91	Do.	$\frac{1}{2}$	4½	27.9	14.6				
Do.	28	Do.	.46	4.15	1.91	Do.	$\frac{1}{2}$	4½	36.8	19.3		62°		

TABLE VII.—*Experiments made at Pembroke Dockyard in 1890, on Basic Open-Hearth Steel.*

Description of Steel.	Distinguishing No.	Plate.			Tensile Tests.			Temperature of Test-house in Degrees Fahrenheit.	Remarks.
		Thickness before Testing.	Width before Testing (Net).	Sectional Area before Testing (Net).	Lengthwise or Across.	Actual Producing Rupture.	Breaking Stress in Tons.		
		Ina.	Ina.	Sq. Ina.	L.	Tons.	Tons.	Per Cent.	
Open-Hearth Do.	1	.47	2.21	1.039	L.	...	...	60°	No. 1 broke in the grip.
Do.	2	.48	2.21	1.061	L.	26.3	24.8	60°	Unperforated plate.
Do.	3	.47	2.22	1.043	A.	27.5	26.3	60°	No. 3 broke outside centres.
Do.	4	.47	2.22	1.043	A.	27.5	26.3	60°	
Do.	5	.49	3.42	1.676	...	42.9	25.6	60°	Holes punched $\frac{1}{4}$ -inch before shaping. See Fig. 1.
Do.	6	.49	3.42	1.676	...	43.3	25.8	60°	Holes punched $\frac{1}{4}$ -inch after shaping. See Fig. 1.
Do.	7	.49	3.37	1.651	...	43.7	26.5	60°	Holes drilled $\frac{1}{4}$ -inch and countersunk through. See Fig. 1.
Do.	8	.49	3.42	1.676	...	43.1	25.7	60°	Holes punched $\frac{1}{4}$ -inch and countersunk to $\frac{1}{4}$ -inch. See Fig. 1.
Do.	9	.49	3.19	1.563	...	45.8	29.3	60°	Holes drilled $\frac{1}{4}$ -inch and countersunk through. See Fig. 1.
Do.	10	.49	3.14	1.539	...	49.5	32.2	60°	Holes punched $\frac{1}{4}$ -inch and countersunk to $\frac{1}{4}$ -inch. See Fig. 1.
Do.	11	.49	3.11	1.524	...	44.0	28.8	60°	Holes drilled $\frac{1}{4}$ -inch. See Fig. 1.
Do.	12	.49	3.17	1.563	...	44.6	28.7	60°	
Do.	13	.50	3.43	1.715	...	52.7	30.7	60°	
Do.	14	.50	3.43	1.715	...	51.3	23.9	60°	

TABLE VIII.—Experiments made at Pembroke Dockyard in 1890, to Ascertain the Effect of Riveting on Basic Open-Hearth Steel.

Description of Steel.	Distinguishing Number.	Nature of Joint.	Plate.			Riveting.		Mode of Fracture.	Breaking Stress in Tons.			Temperature of Test-house in Degrees Fahr.	Remarks.
			Thick-ness before Testing.	Width before Testing (Net).	Sectional Area before Testing (Net).	Nature.	Diameter of Rivet.	Pitch of Rivets.	Actual Producing Rupture.	Per Square Inch. Of Area before Testing.	Mean Results.		
			Inch.	Inch.	Sq. Inch.		Inch.	Diam.	Tons.	Tons.	Tons.		
Open-Hearth	15	Double riveted, single strapped butt. See Fig. 2.	.50	2.42	1.21	Pan heads, countersunk points.	$\frac{3}{4}$	...	35.0	29.0	28.9	62°	All plates punched, butt straps drilled.
Do.	16	Do.	.50	2.42	1.21	Do.	$\frac{3}{4}$	...	34.8	28.8	29.3	62°	
Do.	17	Do.	.50	2.68	1.34	Pan heads, snap points.	$\frac{3}{4}$	...	39.5	29.5		62°	
Do.	18	Do.	.50	2.68	1.34	Do.	$\frac{3}{4}$	...	39.1	29.1	30.4	62°	
Do.	19	Do.	.48	3.13	1.502	Pan heads, countersunk points.	$\frac{3}{4}$	...	45.8	30.4		62°	
Do.	20	Do.	.48	3.13	1.502	Do.	$\frac{3}{4}$	...	45.8	30.4	28.3	62°	
Do.	21	Do.	.48	3.38	1.622	Pan heads, snap points.	$\frac{3}{4}$	...	45.6	28.1		62°	
Do.	22	Do.	.48	3.38	1.622	Do.	$\frac{3}{4}$	...	46.4	28.6	29.8	62°	
Do.	23	Treble riveted, single strapped butt. See Fig. 3.	.51	3.23	1.647	Do.	$\frac{3}{4}$	$3\frac{1}{2}$	48.0	29.1		62°	
Do.	24	Do.	.51	3.23	1.647	Do.	$\frac{3}{4}$	$3\frac{1}{2}$	50.4	30.6	28.0	62°	
Do.	25	Do.	.51	3.45	1.76	Do.	$\frac{3}{4}$	4	48.2	27.4		62°	
Do.	26	Do.	.51	3.45	1.76	Do.	$\frac{3}{4}$	4	50.3	28.6	27.6	62°	
Do.	27	Do.	.51	3.99	2.035	Do.	$\frac{3}{4}$	4	55.4	27.2		62°	
Do.	28	Do.	.51	3.99	2.035	Do.	$\frac{3}{4}$	4	57.1	28.1		62°	

TABLE IX.—*Experiments made at Pembroke Dockyard in 1890, on Basic Open-Hearth Steel.*

Description of Steel.	Distinguishing No.	Plate.				Tensile Tests.			Temperature of Test-house in Degrees Fahrenheit.	Remarks.
		Thickness before Testing.	Width before Testing (Net).	Sectional Area before Testing (Net).	Lengthwise or Across.	Actual Producing Rupture.	Breaking Stress in Tons.	Extension in Eight Inches.		
		Ina.	Ina.	Sq. Ina.	L.	Tons.	Tons.	Per Cent.		
Open-Hearth	1	.49	2.22	1.088	L.	28.1	25.8	31.2	66°	Unperforated plate.
Do.	2	.49	2.22	1.088	L.	27.9	25.6	32.5	66°	Holes punched $\frac{1}{4}$ -inch before shaping. See Fig. 1.
Do.	3	.48	2.24	1.075	A.	26.2	24.3	26.2	66°	Holes punched $\frac{1}{4}$ -inch after shaping. See Fig. 1.
Do.	4	.48	2.23	1.070	A.	26.1	24.4	26.2	66°	Holes drilled $\frac{1}{4}$ -inch and countersunk to $\frac{1}{4}$ -inch. See Fig. 1.
Do.	5	.49	3.36	1.646	...	42.2	25.6	...	66°	Holes punched $\frac{1}{4}$ -inch and countersunk through. See Fig. 1.
Do.	6	.49	3.36	1.646	...	43.1	26.2	...	66°	Holes punched $\frac{1}{4}$ -inch and countersunk to $\frac{1}{4}$ -inch. See Fig. 1.
Do.	7	.49	3.29	1.612	...	41.7	25.9	...	66°	Holes punched $\frac{1}{4}$ -inch and countersunk to $\frac{1}{4}$ -inch. See Fig. 1.
Do.	8	.49	3.29	1.612	...	41.7	25.9	...	66°	Holes drilled $\frac{1}{4}$ -inch and countersunk through. See Fig. 1.
Do.	9	.49	2.78	1.362	...	38.4	23.2	...	66°	Holes punched $\frac{1}{4}$ -inch and countersunk to $\frac{1}{4}$ -inch. See Fig. 1.
Do.	10	.49	2.78	1.362	...	36.2	23.5	...	66°	Holes drilled $\frac{1}{4}$ -inch. See Fig. 1.
Do.	11	.49	2.93	1.436	...	39.1	27.2	...	66°	
Do.	12	.49	2.93	1.436	...	38.3	26.7	...	66°	
Do.	13	.49	3.48	1.705	...	48.4	28.4	...	66°	
Do.	14	.49	3.48	1.705	...	48.4	28.4	...	66°	

TABLE X.—Experiments made at Pembroke Dockyard in 1890, to Ascertain the Effect of Riveting on Basic Open-Hearth Steel.

Description of Steel.	Distinguishing Number.	Plate.			Riveting.		Mode of Fracture.	Breaking Stress in Tons.			Temperature of Test in Degrees Fahr.	Remarks.
		Nature of Joint.	Thick-ness before Testing.	Width before Testing (Net).	Sectional Area before Testing (Net).	Nature.	Diameter of Rivet.	Pitch of Rivets.	Actual Producing Rupture.	Per Square Inch. Of Area before Testing.		
Open-Hearth	15	Double riveted, single strapped butt. See Fig. 2.	.49	Ins. 2.32	Sq. Ins. 1.137	Pan heads, countersunk points.	Ins. $\frac{3}{4}$	Diam. ...	Tons. 29.7	Tons. 26.1	66°	All plates punched, butt straps drilled.
Do.	16	Do.	.49	2.32	1.137	Do.	$\frac{3}{4}$	...	29.9	26.3	66°	
Do.	17	Do.	.49	2.39	1.269	Pan heads, snap points.	$\frac{3}{4}$	...	...	29.4	...	
Do.	18	Do.	.49	2.59	1.269	Do.	$\frac{3}{4}$	...	...	28.9	...	
Do.	19	Do.	.49	3.18	1.558	Pan heads, countersunk points.	$\frac{3}{4}$	...	43.1	27.6	66°	
Do.	20	Do.	.49	3.18	1.558	Do.	$\frac{3}{4}$	...	43.7	28.1	66°	
Do.	21	Do.	.49	3.43	1.681	Pan heads, snap points.	$\frac{3}{4}$	...	49.3	29.3	66°	
Do.	22	Do.	.49	3.43	1.681	Do.	$\frac{3}{4}$	...	48.2	28.7	66°	
Do.	23	Treble strapped, single strapped butt. See Fig. 3.	.48	3.21	1.541	Do.	$\frac{3}{4}$	3 $\frac{1}{2}$	...	28.8	...	66°
Do.	24	Do.	.48	3.21	1.541	Do.	$\frac{3}{4}$	3 $\frac{1}{2}$	...	29.0	...	66°
Do.	25	Do.	.48	3.61	1.733	Do.	$\frac{3}{4}$	4	...	27.4	...	66°
Do.	26	Do.	.48	3.61	1.733	Do.	$\frac{3}{4}$	4	49.0	28.3	66°	66°
Do.	27	Do.	.48	3.98	1.910	Do.	$\frac{3}{4}$	4 $\frac{1}{2}$	...	27.6	66°	66°
Do.	28	Do.	.48	3.98	1.910	Do.	$\frac{3}{4}$	4 $\frac{1}{2}$	...	27.4	66°	66°

TABLE XI.—Experiments made at Pembroke Dockyard in 1890, on Basic Open-Hearth Steel.

Description of Steel.	Distinguishing No.	Plate.		Tensile Tests.			Temperature of Test—house in Degrees Fahrenheit.	Remarks.	
		Thickness before Testing.	Width before Testing (Not).	Sectional Area before Testing (Net).	Breaking Stress in Tons.				Extension Per Square Inch of Area before Testing.
					Actual Producing Rupture.	Per Square Inch of Area before Testing.			
Open-Hearth	1	Ins. .47	Ins. 2.2	Sq. Ins. 1.034	Tons. 32.4	Tons. 31.3	Per Cent. 25	Unperforated plate. No. 4 broke outside centres. Holes punched $\frac{3}{4}$ -inch before shaping. See Fig. 1. Holes punched $\frac{3}{4}$ -inch after shaping. See Fig. 1. Holes drilled $\frac{3}{4}$ -inch and countersunk through. See Fig. 1. Holes punched $\frac{3}{4}$ -inch and countersunk to $\frac{3}{4}$ -inch. See Fig. 1. Holes drilled $\frac{3}{4}$ -inch. See Fig. 1.	
Do.	2	.47	2.2	1.034	32.4	31.3	26.2		
Do.	3	.47	2.21	1.039	32.8	31.5	20.0		
Do.	4	.47	2.21	1.039	32.1	30.9	...		
Do.	5	.47	3.4	1.598	46.0	28.8	...		
Do.	6	.47	3.4	1.598	47.8	29.9	...		
Do.	7	.47	3.4	1.598	47.3	29.6	...		
Do.	8	.47	3.4	1.598	49.1	30.7	...		
Do.	9	.47	3.11	1.462	46.4	31.8	...		
Do.	10	.47	3.11	1.462	46.9	32.1	...		
Do.	11	.47	3.1	1.457	48.2	33.1	...		
Do.	12	.47	3.1	1.457	48.2	33.1	...		
Do.	13	.48	3.4	1.632	52.7	32.3	...		
Do.	14	.48	3.4	1.632	51.8	31.7	...		

TABLE XII.—Experiments made at Penbroke Dockyard in 1890, to Ascertain the Effect of Riveting on Basic Open-Hearth Steel.

Description of Steel.	Mixing Number.	Nature of Joint.	Plate.		Riveting.			Breaking Stress in Tons.			Remarks.		
			Thick- ness before Testing.	Width before Testing (Net).	Sectional Area before Testing (Net).	Nature.	Diam- eter of Rivet.	Pitch of Rivets.	Mode of Fracture.	Actual Produc- ing Rupture.		Of Area before Testing.	Mean Results.
			Inch.	Inch.	Sq. Inch.	Pan heads, countersunk points.	Inch.	Diam.	Tons.	Tons.	Tons.	Tons.	
Open-Hearth	15	Double riveted, single strapped butt. See Fig. 2.	.48	2.28	1.094	Pan heads, countersunk points.	$\frac{3}{4}$	...	Plate broke.	36.4	33.2	32.8	70°
Do.	16	Do.	.48	2.28	1.094	Do.	$\frac{3}{4}$	...	Do.	35.5	32.4	32.4	
Do.	17	Do.	.48	2.55	1.224	Pan heads, snap points.	$\frac{3}{4}$	...	Do.	35.7	29.2	29.2	70°
Do.	18	Do.	.48	2.55	1.224	Do.	$\frac{3}{4}$	...	Do.	35.7	29.2	29.2	
Do.	19	Do.	.47	3.08	1.448	Pan heads, countersunk points.	$\frac{3}{4}$	...	Do.	47.1	32.5	32.3	70°
Do.	20	Do.	.47	3.08	1.448	Do.	$\frac{3}{4}$	...	Do.	46.4	32.1	32.1	
Do.	21	Do.	.47	3.33	1.565	Pan heads, snap points.	$\frac{3}{4}$	...	Do.	48.7	31.1	31.8	70°
Do.	22	Do.	.47	3.33	1.565	Do.	$\frac{3}{4}$	...	Do.	50.9	32.5	32.5	
Do.	23	Treble riveted, single strapped butt. See Fig. 3.	.47	3.19	1.499	Do.	$\frac{3}{4}$	...	Do.	47.8	31.8	31.8	70°
Do.	24	Do.	.48	3.19	1.531	Do.	$\frac{3}{4}$	...	Do.	48.7	31.8	31.8	
Do.	25	Do.	.47	3.68	1.73	Do.	$\frac{3}{4}$	...	Do.	52.0	30.1	30.5	70°
Do.	26	Do.	.465	3.68	1.711	Do.	$\frac{3}{4}$	...	Do.	53.1	31.0	31.0	
Do.	27	Do.	.47	3.80	1.828	Do.	$\frac{3}{4}$	...	Do.	56.5	30.9	30.9	70°
Do.	28	Do.	.47	3.89	1.828	Do.	$\frac{3}{4}$	...	Do.	55.8	30.5	30.5	

All plates
punched,
butt
straps
drilled.

TABLE XIII.—Experiments made at Pembroke Dockyard in 1891, on Basic Open-Hearth Steel.

Description of Steel.	Distinguishing No.	Plate.		Length-wise or Across.	Tensile Tests.			Temperature of Test-house in Degrees Fahrenheit.	Remarks.	
		Thickness before Testing.	Width before Testing (Net).		Sectional Area before Testing (Net).	Breaking Stress in Tons.				Extension in Eight Inches.
						Actual Producing Rupture.	Per Square Inch of Area before Testing.			
Open-Hearth	1	Ins. .47	Ins. 2.25	Sq. Ins. 1.057	L.	Tons. 29.0	Tons. 27.4	Per Cent. 27.5	Unperforated plate.	
Do.	2	.47	2.22	1.043	L.	29.1	27.9	26.9		
Do.	3	.48	2.24	1.075	A.	29.7	27.6	25.0		
Do.	4	.48	2.22	1.066	A.	29.5	27.6	23.7		
Do.	5	.47	3.40	1.598	...	39.1	24.4	...	Holes punched $\frac{1}{4}$ -inch before shaping. See Fig. 1.	
Do.	6	.47	3.40	1.598	...	39.7	24.9	...		
Do.	7	.47	3.40	1.598	...	39.2	24.5	...	Holes punched $\frac{1}{4}$ -inch after shaping. See Fig. 1.	
Do.	8	.47	3.40	1.598	...	38.2	23.9	...		
Do.	10	.47	3.07	1.443	...	41.7	28.9	...	Holes drilled $\frac{1}{4}$ -inch and countersunk through. See Fig. 1.	
Do.	11	.47	3.14	1.476	...	40.8	27.7	...		
Do.	12	.46	3.18	1.463	...	40.8	27.9	...	Holes punched $\frac{1}{4}$ -inch and countersunk to $\frac{1}{4}$ -inch. See Fig. 1.	
Do.	13	.46	3.37	1.550	...	43.5	28.1	...		
Do.	14	.47	3.37	1.584	...	44.0	27.8	...	Holes drilled $\frac{1}{4}$ -inch. See Fig. 1.	

TABLE XIV.—Experiments made at Pembroke Dockyard in 1891, to Ascertain the Effect of Riveting on Basic Open-Hearth Steel.

Description of Steel.	Distinguishing Number.	Nature of Joint.	Plate.		Riveting.			Mode of Fracture.	Breaking Stress in Tons.			Temperature of Test-house in Degrees Fahr.	Remarks.
			Thick-ness before Testing.	Width before Testing (Net).	Sectional Area before Testing (Net).	Nature.	Diameter of Rivet.		Pitch of Rivets.	Actual Producing Rupture.	Of Area before Testing.		
Open-Hearth	15	Double riveted, single strapped butt. See Fig. 2.	Ina. .46	Ina. 2.30	Sq. Ina. 1.058	Pan heads, countersunk points.	Ina. $\frac{3}{8}$	Diam. ...	Tons. 31.7	Tons. 30.0	Tons. 30.5	64°	All plates punched, butt straps drilled.
Do.	16	Do.	.47	2.30	1.081	Do.	$\frac{3}{8}$	...	33.5	31.0	32.5		
Do.	17	Do.	.47	2.56	1.203	Pan heads, snap points.	$\frac{3}{8}$	...	39.3	32.6	32.5		
Do.	18	Do.	.46	2.56	1.178	Do.	$\frac{3}{8}$	...	38.2	32.4	28.6		
Do.	19	Do.	.46	3.12	1.435	Pan heads, countersunk points.	$\frac{3}{8}$	...	42.0	29.2	28.6		
Do.	20	Do.	.47	3.12	1.466	Do.	$\frac{3}{8}$	...	41.1	28.0	28.8		
Do.	21	Do.	.47	3.38	1.589	Pan heads, snap points.	$\frac{3}{8}$	...	46.9	29.5	28.8		
Do.	22	Do.	.47	3.38	1.589	Do.	$\frac{3}{8}$	...	44.9	28.2	31.1		
Do.	23	Treble riveted, single strapped butt. See Fig. 3.	.46	3.24	1.490	Pan heads, snap points.	$\frac{3}{8}$	...	48.2	32.3	31.1		
Do.	24	Do.	.47	3.24	1.523	Do.	$\frac{3}{8}$	...	45.8	30.0	31.0		
Do.	25	Do.	.46	3.67	1.688	Do.	$\frac{3}{8}$	...	52.0	30.8	31.0		
Do.	26	Do.	.46	3.67	1.688	Do.	$\frac{3}{8}$	...	52.7	31.2	31.0		
Do.	27	Do.	.47	4.08	1.918	Do.	$\frac{3}{8}$	...	54.5	28.4	29.1		
Do.	28	Do.	.47	4.08	1.918	Do.	$\frac{3}{8}$	...	57.1	29.8	29.1		

DISCUSSION.

The PRESIDENT said the very interesting and valuable results which Mr. White had communicated to them would, he felt sure, be received by basic steel manufacturers with a degree of warmth which was perhaps proportionate to the time they had been waiting for the information now given them. They would doubtless have an interesting discussion upon the paper, and he would first call upon Mr. Gilchrist.

Mr. P. C. GILCHRIST did not think he could add anything to Mr. White's paper, except to point out that three out of four makers of basic open-hearth steel (who supplied the steel referred to in the paper) supplied it from pig iron of the ordinary basic composition, with from 2·6 to 2·7 of phosphorus. He might perhaps mention that, when basic steel was given up for shipbuilding some years ago, the acid steel made by the same firm was given up at the same time, so that this suspension was due, not to the process itself, but to some other cause, which might happen to any process. He thought that those interested in the basic process, and steel users generally, were much indebted to Mr. White for his very valuable paper.

Mr. ARTHUR COOPER thought Mr. White was to be congratulated upon the very efficient and thorough manner in which he had carried out his experiments. The results given in Table I. confirmed the results of some experiments on a very extensive scale made at the North-Eastern Steel Works in Middlesbrough, in the early stages of the basic Bessemer process, at the time they were supplying material under Lloyd's survey. He had no experience with the basic open-hearth process, but he was not surprised that Mr. White had arrived at the conclusion that had been stated, viz., to admit basic open-hearth steel on the same terms as acid. He (Mr. Cooper) saw no reason to doubt that, when Mr. White had completed the further trials with basic Bessemer steel, his results would be equally satisfactory. With regard to their own works, they had supplied something like 1000 tons of basic Bessemer in

their early days, and the quality of the steel was satisfactory; but at that time they had a large demand for a much softer quality, and it suited their arrangements and convenience very much better to confine themselves to that softer trade for which their plant was laid out, rather than to follow up the manufacture of shipbuilding steel; for, as they had no appliances for supplying that in the finished form, all the blooms and slabs for shipbuilding material had to be rolled at other works, where there were angle mills and plate mills, and the results, from a commercial point of view, were anything but satisfactory.

He thought he had had a little to do with the suggestion that there should be a lower standard for basic; but the idea was not to get the minimum standard reduced from 26 tons to 23, but to get a lower or additional class fixed, in order to admit soft Bessemer steel or ingot iron, and so enable that softer material to compete with wrought iron. He did not expect, for this softer material, to get a large reduction from the iron scantlings, but it was thought that, with that, a sort of middle class might be formed, and that of such material a ship might be built, superior to iron in point of quality, and at about the same cost. He quite agreed with what Mr. White had said later on in his paper, viz., that, owing to the development of the process, it was now quite as easy, and nearly, if not quite as cheap, to make steel of higher tensile strain, as it was to make it of a softer quality.

Mr. SNELUS, F.R.S., said it was gratifying to hear the high character which Mr. White had given to the basic process, which had been more than corroborated by the statement of Mr. Carnegie. He would call attention to the most remarkable results which Mr. White had observed in the riveted samples, because it looked rather as if there was something wrong if a perforated plate would give no reduction in tensile strength. That was quite unique. Mr. White had pointed out that the loss in punching ordinary plates averaged 22 per cent., while in the basic process there was no loss whatever. If they could get a material which was 22 per cent. stronger than they had had before, an enormous stride would have been made. It seemed, then, that some reason must be given for this great improvement, and it occurred to him that the reason was that the

basic metal was a purer material than they had been used to get before, while the difference in the results was due to the amount of purity which had been obtained by the different manufacturers. That greater purity and increase of strength could be obtained was a very important point, and he thought it only required more experience in the manufacture to add that further valuable result—uniformity. When greater uniformity had been attained, he thought they had in England the means of producing basic steel as cheaply as any other country in the world.

But that was not all. Something more was needed. They needed customers for that basic material when it had been made. He hoped, therefore, some means would be found by which they could find employment for the steel-works that were unemployed. He happened to be at Seraing the week before last, and found that a Belgian firm had taken out of English hands the manufacture of material for new Chinese ironworks, so that, although English engineers had been sent out there to erect the works, they had lost their ground, and Belgian engineers had got the contract. There must be some serious reason for this loss of our trade. He hoped that the case he had cited would be a warning, and that they would not cease to show the energy with which they had hitherto been credited in the iron and steel trades.

Mr. JAMES RILEY said he thought that the last remark which Mr. Snelus had made would tend to remind them of a fact which, he feared, was not so frequently remembered at their meetings as it ought to be—he meant the exceedingly sympathetic attitude which Mr. White, Mr. Martell, and others, holding high positions such as they did, had invariably maintained towards themselves. Some of them knew, perhaps, better than others, how much they were indebted to those gentlemen for the kindly assistance which they had rendered them from time to time in the researches which had been prosecuted, sometimes, indeed, on their initiative. He thought that that was a very fitting opportunity to refer to the indebtedness of the Institute to Mr. White, who had read papers to them frequently, and in private had helped them very greatly indeed. Let them consider for a moment how different might have been the history of the last ten or fifteen years with regard

to mild steel had the attitude of Sir Nathaniel Barnaby, Mr. White, Mr. Martell, and others, been even of the passive character which they sometimes met with, and very heartily detested. They had not, he was pleased to say, taken up that position towards them, but had encouraged them very greatly in private, and as they all knew, in public at their meetings. He, for one, therefore begged to tender his thanks to Mr. White and Mr. Martell, and to other gentlemen concerned, for the assistance they had rendered them from time to time.

The other remarks Mr. Snelus had made were not, perhaps, very judicious ones, because they tended to awaken some thoughts which would occasionally come into their minds as to the cause of the "idleness" of the steel-works of this country. How different would have been the history of the steel trade (and especially of the hæmatite iron trade of Cumberland) of this country if this exceedingly interesting and valuable process had been postponed in its discovery for, say, a quarter of a century. Perhaps Mr. Snelus had unfortunately pointed out the reason why the iron and steel trade of this country had not flourished to the extent that it would have done if the new process had been confined to this little island. Unfortunately for us, the benefit had been cosmopolitan. It had been, he believed, detrimental to the steel trade of Great Britain, whether from want of energy, or from some other cause.

He now desired to come to the question more immediately before the meeting, viz., the value of basic open-hearth steel. Upon that point he endorsed every word that had fallen from the author of the paper. He (Mr. Riley) had had occasion to have examinations made over and over again, and he was convinced of the great value of the material brought out in the open-hearth process. He knew nothing from personal experience of the Bessemer basic process, as it had not come under his observation; but, as bearing on that point, he might be allowed to go back to what seemed now to be rather ancient history. At the Glasgow meeting in 1885, he ventured to make these remarks: "I would venture, however, to say a word or two with regard to basic steel. I am strongly of opinion that a mistaken method has been adopted in working the basic process. If ever the basic process is to be a perfect success in Great Britain, or in any other country, and is to

produce steel of a perfectly reliable character, such as we can accept without fear, it must be worked out in the open-hearth furnace, and not in the Bessemer converter." He had stated that very strongly at the time, and he then said he could give his reasons; but the opinion he then expressed had since, of course, been modified very considerably. He knew that Mr. Cooper, and one or two firms in Scotland, had demonstrated that the basic steel made by the Bessemer process was undoubtedly a remarkable product, and might be used with confidence; but he still thought, and his opinion appeared to be borne out by the results obtained by Mr. White, that the best basic product would be obtained in the open-hearth furnace, just as the best acid product was also obtained in that furnace.

He noticed that the last few lines of the paper referred to the manufacture of tubes from basic steel. He (Mr. Riley) had followed the process referred to for that and kindred objects for a very considerable time. He might say that their friend, Mr. Martell, somewhat differing from his previous practice, yet wisely (?), said, "Never until you have demonstrated to me the value of the material coming out of the furnace—but not that alone—not until you submit to me, or my representatives, the material that you put into the furnace, will I accept the material." Then he (Mr. Riley) said, "You have gone out of your way; you have taken up a position you have nothing to do with; do what you like with the material I bring out of the furnace, but I never will tell you what I put in." There they stood to-day. Mr. Martell had not had—it was *his* loss—any of the basic material, but still he might tell Mr. Martell that if he (Mr. Riley) had anything very choice or special required, that material would be made in the basic open-hearth furnace, and other furnaces would do for that material which went to the shipbuilders.

Sir ALFRED HICKMAN said he thought in the few observations Mr. Cooper had made he somewhat unwittingly showed that he was still determined to be in advance of his time. He addressed Mr. White as "Sir William." He (Sir A. Hickman) thought they would all agree that in that he was only anticipating the future, a future which they would all be glad to welcome. He most

cordially concurred with Mr. Riley in thanking Mr. White for his action with reference to basic steel. He thought that not only were basic steel makers indebted to him, but the whole community, inasmuch as the basic process was an established process, whether they adopted it or not. Our competitors abroad had it, and if we had it not we should most certainly be left behind. With reference to the comparison between basic and acid steel, it appeared to him that the ideal process must be the basic. The quality of acid steel must be dependent, as Mr. Riley had said, upon what went into the furnace; but it was impossible in practice, even if they knew what the pig iron was, to say what every bit of the scrap was. The result was that the acid process must be to some extent uncertain as compared with the basic. He was free to admit that at present the basic process was not perfected. He thought, however, they were progressing, and that very rapidly, towards what must ultimately be something like perfection.

It was a noticeable circumstance that in the paper they were to be favoured with by Colonel Dyer, who was undoubtedly one of the highest authorities on the question of the purity of metals, he adopted a basic furnace for the production of the ideally pure material which he wished to produce. A distinction had been drawn between the Bessemer and the open-hearth basic process, and Mr. Riley, who was a great authority on the subject, had placed the weight of his *ipse dixit* in favour of the open-hearth, but as he had told them, he had had no experience whatever of Bessemer steel. Sir Alfred Hickman thought that had been very fairly stated by him, and the fact fully accounted for the conclusions at which he had arrived. With reference to Mr. White's paper, he might say that four years ago, when the experiments were made, there was greater certainty about the results of the open-hearth than the Bessemer process, but so far as Sir Alfred's experience went, that difference had now been largely removed, owing to improvements in detail, but mainly by the rather ingenious invention of introducing the ferro-manganese, and any additional carbon that might be required, into the Bessemer vessel, enclosed in a wooden box. He would not attempt any scientific explanation in the presence of the gentlemen he saw

around him, as that would be presumption on his part, but he could tell them that the practical result in his own works was that less ferro was required, and that the resulting metal was more regular and more reliable.

It had been suggested by some of his scientific friends, that by passing ordinary ferro through the cinder, a reaction took place in the cinder which caused some of the phosphorus in it to be re-absorbed into the metal. He would express no opinion upon that point. He might perhaps be allowed to say, in conclusion, that as a maker of both open-hearth and Bessemer steel, if he had anything to make the quality of which was of extraordinary importance, he should never think of producing it in the open-hearth furnace, but always in the Bessemer converter.

Colonel DYER said he desired to make a few remarks, not with a view of criticising Mr. White's very valuable paper, but rather to ask him if he had had the opportunity of carrying on further experiments to supplement the exceedingly valuable results he had already given when the experiments were carried on, by registering exactly what portion of the plate the specimens were cut from, and also at the same time registering the exact position which those specimens would have occupied in the ingot. He had been led to make those remarks because he had been carrying on lately some experiments with basic steel, and he found that when basic steel was made containing a very small percentage of carbon, the steel almost invariably contained a very large percentage of oxide. When that oxide was in combination, or rather was in the same ingot with impurities, he found that those impurities were, as it seemed, greatly emphasised, and the solidification of the ingot, as they all knew, drove most of the impurities towards the final point of solidification along its axis. It would be exceedingly interesting to know whether, possibly, in some of the earlier experiments with basic steel plates, where they obtained bad results with the basic process, it was not possible that the irregular results produced by that process in the plate were or were not due to the fact of the impurities having all been driven to one particular portion of the plate, and that, although the outside plates gave exceedingly good tests, probably inside across the

axis of the ingot, they would get those irregular tests. He did not say that it occurred in every case, because he found in experiments he had carried on, and which he hoped some day to submit to the Institute, that in the cases where an ingot did not contain that large percentage of oxide to which he had been alluding, the impurities did not seem to have the same bad effect that they had where the ingot contained the large percentage of oxide. He had not carried on sufficient experiments to make quite sure whether that was the positive result, but all he had done pointed in that direction.

He thought it would be very valuable indeed if Mr. White, when he continued his experiments, would give the Institute the details, and make known exactly where the specimen was cut in reference to the axis of the ingot. Unfortunately he did not know of any test by which they could determine the amount of oxide in steel. There were numerous methods, but none, so far as he knew, had been very successful, and therefore they were working to some extent in the dark, and they had to depend entirely upon chemical results to know whether an ingot from the basic furnace contained, besides phosphorus, sulphur, and other impurities, a greater or less degree of the oxide, which they had found by experiment had a very extraordinary effect upon steel. He did not know of any test; but if Sir Frederick Abel could help them, and give them some test by which they could determine the amount of oxide in steel, it would be an exceeding valuable thing, and would assist to elucidate the irregularities sometimes found in plates made by the basic process.

Mr. E. RILEY said there could be no question about the importance of the presence of oxygen in steel, because there were so many cases in which they could not explain the bad quality of steel from any other cause than the presence of oxygen. Perhaps he might be allowed to mention a case showing how a little oxygen in steel would affect the quality. Some years ago he was consulted as to the manufacture of horse-shoe nails. It was a very curious thing, with those horse-shoe nails, that one out of twenty would turn out bad and brittle, while the others were perfect. He investigated the matter, and found that the bad nails were perfectly

free from carbon, and in going over the works the matter was very readily explained. The nails, after being made by machinery, were annealed in a great cast-iron pan. The cast-iron pan was covered with a lid, and luted all round. It was found that the annealing had been rather too long, and the consequence was that all round the edge of the lid the nails were burnt, the steel absorbed oxygen, and the nails became brittle; and thus the whole thing was explained.

Mr. B. MARTELL said, before making any remarks on the paper, he was very pleased indeed to have an opportunity of expressing his thanks to Mr. Riley for his appreciation of the small service which Lloyd's had rendered in connection with the steel manufacture. They were so much accustomed to be criticised adversely, and to be regarded by some as rather obstructors than assistants in doing anything at all with regard to steel, that it was really quite refreshing to hear a gentleman in Mr. Riley's position, and of his great ability, marking his appreciation of any services rendered by Lloyd's Register Committee. The Institute was greatly indebted to Mr. White for placing his results before it. It had been often said, and truly, that the assistance that could be got from the Admiralty would be of infinitely small importance. That was the case formerly, when they knew that most valuable information was lying at the Admiralty Offices, and it was impossible for an outsider to learn the results of their labours—labours, he might say, conducted at the public expense. Under the new *régime* they saw what a difference there was. It was formerly said that they could not obtain the sanction of the Admiralty, but the present director of naval construction evidently could obtain the sanction of the Admiralty to put before them valuable results of this kind. The value of it was the greater when it was considered that Mr. White had not waited till the whole series of tests had been made, but that what few he had got he immediately put before them for the information of the public generally. They were greatly indebted to Mr. White, if only for bringing these valuable results forward. But all in that room who had any knowledge of the steel manufacture would know what unsatisfactory results they had had when steel made by the basic process

was first introduced. It was not necessary to go into that, because it was well known; in fact, those results were so unsatisfactory that it was quite unnecessary that Lloyd's Register Committee should say that they could not accept steel made by that process, because such distrust was awakened in the minds of shipbuilders and shipowners, particularly on the North-East coast, that they would not look at it. The very name of it was like a red rag shown to a bull.

Since that time, for a number of years, no active measures whatever had been taken to produce basic steel for shipbuilding purposes. Firms had produced basic steel, but none of them came to Lloyd's Committee to ask them to undertake the testing, to see whether steel could be produced of a satisfactory character, that would pass their requirements for shipbuilding purposes, till very recently. The paper was, therefore, the more opportune. Mr. Gilchrist, with his usual enterprise, had forced this question to the front. He doubtless knew what improvements had been made in the manufacture of basic steel by this process, and knowing as he did that steel could be so produced of a perfectly reliable character, he wrote stating that he and some of his friends had determined on building a steamer of something like 2000 tons entirely of basic steel, and asked that the quality of this steel should be ascertained. He (Mr. Martell) was pleased to say they deserved somewhat the congratulations of Mr. Riley in this respect, that Lloyd's Registry did not feel that they should be obstructive. Very properly, Mr. Riley said it did not matter by what process the material was produced if the finished material answered the tests and was of a perfectly reliable character. No doubt he (Mr. Martell) did say what Mr. Riley had mentioned, and he thought it was very pertinent to this question. Whether Mr. White was shirking the question advisedly or not he did not know, but up to very recently he had known that steel, to pass their tests, either by the Bessemer process or by the open-hearth process, could not be produced, and had not been produced from Cleveland ore. Owing to the amount of phosphorus it contained, varying from, as he understood, 2·5 to 3 per cent., steel fit for shipbuilding purposes had been made from it by either process. That was a matter of considerable importance, because the quality of the

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material ingredients from which the steel was produced, as was well recognised, had a most important bearing.

Mr. Gilchrist, having made this application, was asked where this steel was to be manufactured, and they found that the angles were to be manufactured at one works and the plates at another. When the angles were ready for testing, they sent one of their most experienced surveyors—one who had experience from the first introduction of basic steel—to the works in order to make crucial tests and in order to see whether it could be relied upon as of uniform quality, and fit to comply with all their requirements. They had not accepted the steel without imposing some very onerous conditions. In the first place, they must have a cold and a temper-bending test from every plate and from every angle manufactured. The steel must also pass their requirements for tensile strength, and must be subject to any tests for quality at the discretion of the surveyor. Mr. Gilchrist had nothing to hide, and, with perfect confidence in the material, said he was prepared to comply with all these requirements.

It was most gratifying to him to stand there, after the great distrust that had been awakened in their minds with reference to steel made by this process, and to be able to confirm the satisfactory results recorded by Mr. White. Lloyd's Committee had gone even further than the Admiralty. Instead of confining themselves to $\frac{1}{2}$ -inch thickness, they had tested steel $\frac{3}{4}$ -inch thick, which was a very important matter. He could only hope that, in the extension of these tests, Mr. White would endeavour to use steel of greater thickness than $\frac{1}{2}$ -inch, and would bring forward the results of such tests. All the bend and temper tests were of a satisfactory character, and uniformly so. There were two hundred and fifty tests of that kind made on different angles. They were of so satisfactory a character that instead of being compelled to accept steel at the lowest limit of strength, the steel averaged something like 30 tons per square inch tensile strength. It went from 26·9 up to 31·5. After being punched, its character was not altered more than that of acid steel would be altered, and all the tests in every respect were up to the requirements. He realised from these tests the probability that the time would come when they would be in a position to accept basic steel with the same

confidence that they were now accepting acid steel, and he could quite join with Mr. White in saying that it would be an enormous public gain to the country if they could do so. Unfortunately they had not had the opportunity of ascertaining what results would accrue from plates as well as from angles made by that process, because Mr. Gilchrist had decided to withdraw from his intention of building a test ship. He feared some time would elapse before they had another opportunity of fully carrying out their experiments. He could easily imagine that, after the satisfactory results got with angles, there would be some makers of steel sufficiently energetic and enterprising to go in and produce both plates and angles, and thus afford an opportunity of seeing what could be done in that direction. When Mr. Evans had a little time to spare, he hoped he would go into the question, and see what could be done in the Cleveland district with Cleveland ore.

He (Mr. Martell) could not speak of plates made by that process, but he hoped they would very soon find plates made with results that would be as satisfactory as with angles. Next came the point raised as to the ingredients. The first steel made by the basic process was found very unsatisfactory, but they were now informed, as a positive fact, that the ore of which it was made contained nearly 3 per cent. of phosphorus. In the steel which had given such satisfactory tests, of which the angles were made, there was only about 1.5 per cent. of phosphorus—an amount, he believed, never exceeded by those manufacturers. It was, therefore, a matter of grave consideration and importance whether satisfactory steel could be produced by that process with a limited amount of phosphorus, and that was a question which he thought Mr. Evans would no doubt be able to throw some light upon. He wished to allude to what had been stated with regard to their acceptance of steel as manufactured on the Continent, particularly in Germany. There was always a large quantity of steel manufactured there by the basic process, and as Lloyd's Register embraced foreign shipping, as well as British, they felt, when the parties appealed to them, that they must endeavour to do all they could to assist them, as well as British manufacturers. Consequently, when they had applied to Lloyd's to send a surveyor, Lloyd's had always sent one. They had been reproached by ship-

builders and steel manufacturers, who asked how it was that whilst they looked with so much scorn upon the steel produced by the basic process in England, they accepted basic steel made on the Continent? The fact was that all the steel made on the Continent that was reliable was made by the open-hearth process. They had not accepted steel manufactured there that had been made by any other than the open-hearth process, and instead of being made from pig of a highly phosphoric character, in all cases the steel was of a select character, containing a very small quantity of phosphorus, while the amount of scrap used was something like 65 to 70 per cent. That was not what was generally regarded on the North-East coast as "basic steel." What was considered in their minds as basic steel was steel made from highly phosphoric ore. Whether it could be done or not he did not know. It had not been done up to the present time, as he had before said. What they specially wanted was to endeavour to do away with the want of confidence and mistrust on the part of the shipbuilders—one of whom he saw present, namely, Mr. Swan of the firm of Armstrong, Mitchell & Co.—and to show that at the present time steel could be made by the basic process with as great confidence as by the acid process.

Sir LOWTHIAN BELL, Bart., F.R.S., said that he belonged to a suspected district, but the pig iron which it produced was not, he thought, as black as it had been painted. He did not know that he had ever met with any Cleveland iron containing more than $1\frac{1}{2}$ or $1\frac{3}{4}$ per cent. of phosphorus. He did not say that rather more might not be found, but he thought the figures he had named would represent an outside average. His friends might be surprised at his indifference in the matter, but in truth he should only be too happy if the iron did, as had been said, contain 3 per cent. of phosphorus; because they had learned now, as he had pointed out twenty years ago, that phosphorus was, what Lord Palmerston described dirt to be, matter in the wrong place, and that if they could get it out of the iron, and lay it on the land, where it was so much required, the phosphorus in the Cleveland pig, instead of being a curse to the neighbourhood, would, in point of fact, be a blessing to the country, and therefore the more

they had in their pig iron the better. And why? In removing the phosphorus from pig iron, it was not the first portion dealt with that presented any difficulty. There was nothing easier than to take pig iron, containing any amount of phosphorus, and to reduce it to almost that which was present in hæmatite pig iron. It was, consequently, the last remnant which constituted the difficulty.

The great advantage of the basic process was, that whatever phosphorus was found in the pig iron, the whole of it, minus this small amount, could be got rid of. In the acid process they began with an operation which, from its very nature, tended to drive all the phosphorus contained in the pig iron into the steel, and it was proposed to substitute, for that, the basic process, whose essence was to withdraw the phosphorus from the metal, and pass it over to the slag. At the Clarence Works, in some experiments which he had carried out on Cleveland metal, he had reduced the phosphorus in the steel to 0·02 per cent. He took the opportunity of sending a specimen of it to Colonel Dyer, and also to Her Majesty's Dockyards, and from both quarters they were pressed to send more of it. Time and other occupations had interfered with the realisation of his intentions, but he by no means despaired of being able to make steel from the phosphoric pig of the Cleveland district which would compete with, and, he hoped, excel, any steel that could be made from ordinary hæmatite by the acid process.

He was glad to have the opportunity of saying a word or two upon the discussion which had taken place. As one of the first promoters of the Iron and Steel Institute, he had foreseen the advantage that would accrue, not only from manufacturers meeting manufacturers, but from manufacturers meeting consumers who afterwards had to deal with their produce. He congratulated not only the Institute, but Lloyd's, on the early recognition of the utility of the Iron and Steel Institute by the constant attendance of gentlemen from that establishment. He referred especially to Mr. Martell, who, so far as he remembered, was always present at the London meetings. But recognition of the merits of the Iron and Steel Institute had not stopped there, and they were honoured that morning, as they had been before, with the presence of the Director of Naval Construction, and a most instructive and

valuable paper had been read by that very distinguished officer. Formerly Her Majesty's Government did not look so favourably upon the Institute. At all events, when he asked the Leader of the House of Commons for a copy of the evidence taken before the Armour Plate Commission, for the use of the Institute, his application was not favourably entertained.

Mr. J. HARDISTY said that the excellent paper that had been read that morning by Mr. White showed that basic steel had very successfully withstood the severe tests that had been applied to it. It was very gratifying to those who had spent the last few years in the manufacture of basic steel by the open-hearth process to know that its merits had at last been officially recognised, and it was now placed on an equal footing with acid steel. So far as his experience went, basic steel was superior to acid. During the past few days he had looked up a number of tests of acid and basic open-hearth steel, and had found that, taking two steels of the same tensile strength, the limit of elasticity was slightly higher with basic than with acid steel, the elastic limit of the acid steel being from 50 to 54 per cent. of the breaking strain, and that of basic 54 to 56 per cent.; while with basic steel made in a chrome furnace, the elastic limit was from 65 to 70 per cent. of the breaking strength, and with very soft steel it went up to 78 per cent. The percentage of elongation was fully equal in basic to what it was in acid, and very often, if the phosphorus was low, the elongation was much greater. Steel could be made by the basic open-hearth process very superior to that made by the acid process. It was softer and tougher than acid steel, for the same analysis; and one great feature of basic steel was that it never failed to weld, and did not crack behind the weld, as acid steel sometimes did when welding boiler tubes. The boiler tubes referred to by Mr. White were made of one-eighth-inch plates, and usually had a tensile strength of $24\frac{1}{2}$ tons per square inch, and stretched 30 to 33 per cent. in a length of eight inches; and that same steel, when rolled into $\frac{7}{16}$ th of an inch or to half-inch plates for fireboxes, had a strength of 24 to 25 tons, and an elongation of 33 to 34 per cent. in eight inches, a result which it would be very difficult to obtain with regularity by the acid process.

With regard to the statement, made by Mr. Martell, that steel had not yet been produced from Cleveland ore to meet Lloyd's requirements, that gentleman was mistaken. He had made some 12,000 tons at the Clarence Works of Sir Lowthian Bell, more than half of which had been supplied to the Indian State Railways, and the tests were more severe than those of Lloyd's or the Admiralty. Basic steel made from common Cleveland pig, to meet the requirements of Lloyd's, the Admiralty, or the Indian State Railways could easily be made, and had been made for the past three years from Cleveland iron alone, no other iron being used to mix with it. Boiler plates had been made from Cleveland iron at Port Clarence, and had been built into locomotive boilers. The tests of that steel were made by Kirkaldy & Son, and showed a tensile strength of 28 tons per square inch, and 28 per cent. elongation in eight inches. In other cases the tensile strength was 30 tons per square inch, with 29·4 per cent. elongation.

Mr. THOMAS WRIGHTSON said that very few remarks had been made upon riveted joints, which was the chief subject of the paper. The most important conclusion to which the author had come was that, with the milder qualities of basic steel, there was practically no loss in punching. Unfortunately, the quality of mildness was incompatible with the conditions of hardness and high tensile strain which it was the fashion to specify. He believed that the future development of basic steel would largely depend upon some change being made in these requirements. At present, both in Great George Street and among naval constructors, a high tensile strain was a condition of all specifications. He could say nothing with regard to the conditions from a ship-building point of view, but he might say something as a practical bridge-builder. Bridge-building had almost grown to an exact science, so far as the design was concerned and the allotment of section to the various portions of the structure; but in designing any member of a bridge a certain amount of tensile strain or compressive strain alone was put upon that portion of the structure, and this only amounted to about one-fourth of the ultimate breaking strain of the member.

He was strongly of opinion that the quality of the margin of

section added to reduce the strain to this point of safety ought to have some relation to the character of the strains that might come upon the structure, and which might be called into effect at any time. As a matter of fact, the strains which had to be taken up by that margin in bridge-building were almost entirely strains of percussion, strains of vibration, and sudden jerks, and that margin would be much more appropriately considered with reference to ductility than to hardness. The change to be hoped for in the future was that the margin would be reduced, so that the ductility might become effective, instead of being impaired, as it is at present, by the condition of hardness being insisted upon. When that was the case, he hoped that the Admiralty would see their way to accept the suggestions which Mr. Cooper said had been put forward by the basic steel makers, and would reduce the condition of tenacity in steel to 23 or 24 tons. They would then have an extremely ductile and efficient material, which, so far as the margin was concerned, between the statical pressure which could be put upon any structure, and those dynamical effects which were produced by vibrations, jerks, and agencies of that kind, would be more efficiently brought to bear to resist those strains.

Mr. J. D. ELLIS said that no one could appreciate more highly than he did the value of the paper which had been read by Mr. White, and the discussion had certainly been exceedingly interesting. Although a very insignificant member of the Institute, he would venture to say that it would be a desirable thing if they could speak of the value of the open-hearth steel, either acid or Bessemer, and of the value of basic steel, without trying to compare one with the other. It appeared to him to be invidious, and it might be very well avoided. Nearly all the remarks had been rather in favour of open-hearth basic steel, and as his experience had been in favour of the Bessemer basic process, it was only fair for him to give it. He had found basic Bessemer steel exceedingly good. He did not like to say that it was better than the other, because that would be contradicting his own views. Mr. White had alluded in his paper to the making of boiler tubes. He was not quite sure whether he was alluding to the

peculiar kind of tubes of which his (Mr. Ellis') firm were the manufacturers, and which they had not been able to make of any other material satisfactorily except Bessemer basic steel. The manufacture of those tubes was one which tried the metal perhaps as much as any manufacture could do.

Mr. W. H. WHITE asked what was the tensile strength ?

Mr. J. D. ELLIS said the tensile strength was very low—something like 24 tons. Those tubes were used for marine boilers, and made by a process patented by a French gentleman. The advantage claimed for them was that they had deep projections in the inside of the tube which greatly increased the production of steam. When he mentioned that they were not much more than one-eighth of an inch thick, and that the projections had to stand up at least half an inch, they might imagine that that was a kind of strip which greatly tried the steel. They had found the greatest possible advantage from using the basic Bessemer steel, which had been manufactured by their excellent friend, Mr. Cooper, the Bessemer medallist of that day.

Mr. C. J. STODDART said he should like to make reference to Mr. Martell's remark, that he would not have an opportunity of testing basic open-hearth plates in consequence of the withdrawal of the basic ship. He took that opportunity of stating that Lloyd's surveyors were at present at the Park Gate Iron and Steel Works investigating the whole of the manufacture of basic steel by the open-hearth process, and that in the course of that investigation they would test plates 1 inch, $\frac{7}{8}$ and $\frac{3}{4}$ of an inch, and other thicknesses. He had no doubt that Mr. Martell might put those results, if they were satisfactory, in such a form as to bring them before the Institute.

A MEMBER said that, as a representative of the open-hearth basic process, it might be desirable to state his experience with reference to oxidising metal. They found that the metal was more apt to oxidise when the carbon was very low, but in the manufacture of steel by the open-hearth basic process they were

able to have a higher grade of iron without lessening the ductility. In point of fact, they needed a slightly higher grade of carbon in order to get the tensile strength, but in doing so, by the addition of a somewhat larger proportion of ferro-manganese, they did not run the same risk of oxidising.

Mr. W. H. WHITE, C.B., F.R.S., in reply, said it was only proper that he should preface what he had to say by acknowledging the too flattering terms in which the work that he had attempted to do for the Institute had been referred to by all the speakers. As a matter of fact, a man who designed ships, especially war ships, was obliged to have some knowledge of a good many things. With regard to his own experience, it might not be known to many present that his training as a naval architect included a considerable amount of training in metallurgy (at the School of Naval Architecture) under their Past President, the late Dr. Percy. From that time it had been a pleasure to him, as opportunities had offered, to follow the progress of the manufacture of steel throughout the country. When mild steel began to be used for shipbuilding purposes by the Admiralty in 1875, it was his duty, as assistant to Sir Nathaniel Barnaby, to visit most of the steel-works of the country to see what was being done, and to gain acquaintance, not merely with products, but with processes. He did not think that the Admiralty for many years past had been open to the charge of non-publication of information. The instance referred to by Sir Lowthian Bell related to an experimental inquiry which ended about twenty-five years ago; and, except for antiquarian interest, he did not suppose that Sir Lowthian Bell would now care to spend time in looking at the proceedings of the Iron Plate Committee.

As to the general principle that it was the duty of users, whether in the public service or outside, to be in close touch with producers, there could be no question. In a paper read last year, describing briefly the exhibits at the Naval Exhibition, he had said that it was by the joint action of the designer and manufacturer that the most perfect results could be achieved. In shipbuilding they had called upon the iron and steel makers of the country to give, in finished forms, coming out of the rolling-mill

or the foundry, sections which formerly had to be built up with many pieces, at great cost, and with considerable loss of strength in relation to weight. One of their great means of progress in the association of lightness with strength, and in the cheapening of production, had been found in the constant effort of manufacturers in this country to meet the requirements of constructors. That must be always true, and perhaps increasingly true as they were going on, and as the power of the manufacturer increased, because he was dealing with such superior qualities of material. For many years past—he was not referring simply to his own time, because he had quitted the public service, and had breathed the free air of private life—long before he was personally responsible for the work, Sir Nathaniel Barnaby had come to the Institute and given the results of experiments on steel, to which reference had been made. The same thing was true with regard to the Institution of Naval Architects and other public bodies. The officers of the Admiralty had for many years acted on the principle that nothing but good could result from mutual discussion between the users and the makers of material.

He might say one other word with regard to the attitude of the Admiralty towards the manufacture of steel. It was true that the Admiralty had never patronised exclusively any mode of manufacture. They had always dealt with material as produced, rather than with the process of production. Mr. Ellis and other speakers appeared to have missed that point. The Admiralty, however, had substantial reasons for not putting steel of shipbuilding quality, made in the converter, upon the same footing as steel made in the open-hearth furnace. That was no novelty. It had been stated thirteen years ago by Sir Nathaniel Barnaby. On the other hand, the Admiralty had never shut out steel made in the converter; they had continued to use it in very large quantities, but not for those portions of the riveted structures of ships which were subjected to high tensile strains. According to many experimental tests, riveted samples of steel of shipbuilding quality, made in the converter, were not so trustworthy as samples made in the open-hearth process. Consequently, in the more important portions of the structure of ships, the Admiralty officers preferred the use of that material which they knew could be better depended upon.

He was speaking not of a single isolated case, but of the experience of many years. If the makers of steel in the converter, whether basic or acid, could produce experimental proof that those repeated occurrences had now been rendered impossible by improvements in manufacture such as those to which Mr. Cooper had alluded, the Admiralty had no prejudice, and desired only to obtain their supplies of shipbuilding materials in the freest and most open manner possible. They dealt with products, not with processes, unless they had some very distinct reason for doubting the trustworthiness of material made by any process. They did not ask officially what went into the furnace, although he believed they knew. They distinguished between a thing being specified and confidential information being given, and he believed manufacturers never distrusted their discretion in the matter, or refused to give information.

In the remarks which Mr. Gilchrist had made, which were far too brief for the meeting, who would have preferred to hear him at greater length on a subject so especially his own, he had mentioned what seemed to have escaped observation, viz., that the steel in three sets of tests was made from pig iron containing from 2.6 to 2.7 per cent. of phosphorus. That was a point which well deserved consideration, although it had been dealt with so thoroughly in the remarks of Sir Lowthian Bell. Colonel Dyer had asked if information could be supplied as to the position of the samples in the plates from which they were cut, and the position of the axis of the ingot in relation to the plates experimented with. He was sorry that that could not be done. It would be understood, in relation to the ingots, that it would be an extremely difficult thing for the user to attempt. Such tests should be made in the works of the makers. As to cutting samples from the plates, all he could say was that the same procedure had been followed with all the plates from which samples were taken. They were all treated in the same way, and, as between the modes of manufacture, the conditions were about equal. He did not say that equally similar conditions held good for the ingots. He did not know about that. They dealt with these matters in a broad and general fashion, and could not be informed of many of the points which were of the greatest importance to makers, and also in

determining the real quality of the material. Mr. Martell suggested that they might extend their experiments to thicker plates. It must have escaped his memory—for their joint papers were read together—that in his (Mr. White's) paper, read before the Institution of Naval Architects in 1887, he gave many tests of basic steel plates up to and above an inch in thickness. In the series of tests mentioned in the present paper, a standard thickness of plate was adhered to, so as to test the quality, and compare, under identical conditions, the effect of riveting upon acid steel and upon basic steel. They had carried out experiments in basic steel plates up to and above an inch in thickness with very satisfactory results. He should like to ask Mr. Martell, simply for the purpose of information, whether, in the tests which he had described, and which were so satisfactory, the basic angles were made by the open-hearth process or in the converter?

MR. MARTELL said that they were made by the open-hearth process.

MR. W. H. WHITE said that Mr. Snelus had referred to some remarks in the paper, and had a little confused two things. He seemed surprised to find that samples in which holes had been drilled gave a higher tensile strength on the remaining sectional area through the holes than unperforated samples had given. If Mr. Snelus would refer to Professor Kennedy's paper, published in the "Proceedings of the Institution of Mechanical Engineers," he would find that was a well-recognised fact, and the reason was easy to see. But there was one explanation he might make in regard to a matter which might have confused Mr. Snelus. In all the important parts of ships, punching was regarded by ship-builders as a necessity. He knew some of their engineering friends thought it was a brutal treatment, but it was not found so. They punched holes in the shell plates, and then were obliged to counter-sink for the riveting. Many years ago they discovered, experimentally, when they were working chiefly with Landore steel made by Mr. Riley, that if they counter-sunk right through, and slightly enlarged the hole made by punching, it entirely removed the damage done in punching. That was the common practice now. They had removed all the damage done in punching, and the figures that he gave were intended to show that when they

had done that with open-hearth steel, whether acid or basic, they practically did not affect the strength of the material by the process of putting in the rivets. That was the important point for them.

Mr. Wrightson had turned back to the first love of the basic steel-makers, although, if he had carried in his mind what Mr. Cooper had said, he would have recognised that those who were most actively engaged in the basic process now did not recommend the concession. Mr. Wrightson had said, Why not cut down the tensile strength to 24 tons, or something like that, and get greater ductility, and have on the whole a better material under the working limits of strength? He (Mr. White) was not speaking of bridge-building. With all respect to Mr. Wrightson, he thought that in building ships they had rather more difficult, and certainly different, conditions to meet. What they had to deal with was this. They had a structure subject to external water-pressure, as well as to strains coming upon it from unequal distribution of weight and buoyancy, from rapid movements, and from internal loads of cargo. A ship was, in fact, a lightly-built structure, stiffened only at intervals (which might vary from 2 to 4 feet) by frames, which had to bear varying and severe strains, and to carry itself and the powerful engines which propelled it through the water. That was a little different from a bridge. They found that with increased tensile strength they got greater stiffness; but stiffness was with them often the limiting condition of the service, and therefore—Mr. Martell could bear him out in that statement—they, as shipbuilders, said that they must not accept a reduction in tensile strength of the steel used in shipbuilding. For other purposes it might be the best way, but not for them. Years ago, when Mr. Riley was at Landore, they went further, and actually determined by experiment that they could safely have an acid mild steel up to 35 tons, and for very light structures it might come to that in shipbuilding. They had now associated with good tensile strength an amount of ductility that served all their purposes. They did not want more ductility; they could not possibly want more than they had in the *Victoria*, which ran ashore with 190 feet of her length over a reef, and the bottom folded up like a thin plate, and the hull was but slightly injured. That was a practical proof, and he could give hundreds

of other instances, that they could, in association with an amount of tensile strength, which was essential to stiffness, get angle ductility, not merely for all ordinary working, but for what they hoped would be the rare accidents which sometimes occurred even to the best regulated ships.

Note.—In the course of the discussion, information was asked for respecting the analysis of the basic steel tested at Pembroke. By the kindness of Mr. Gilchrist, I am now able to give the following particulars for the steel plates tested in 1890 :—

	Tables 7 and 8.	Tables 9 and 10.	Tables 11 and 12.		Tables 13 and 14.
Carbon	·142	·16	·1	·28	·11
Silicon	...	trace	...	...	trace
Sulphur	...	·037	·033	·031	·041
Phosphorus	·068	·022	·047	·057	·055
Manganese	·56	·56	·298	·377	·76

A similar analysis for some successful rivet steel, made in the basic open-hearth furnace, gave carbon ·29, sulphur ·021, phosphorus ·066, manganese ·584.

The PRESIDENT said that after the cordial reception which had been given to Mr. White's paper, it would be a work of supererogation on his part to propose that a vote of thanks be given to him for his communication, the value of which had been so thoroughly recognised. It was gratifying to observe the liberal manner in which Mr. White appreciated, as he had always done, the important principle of reciprocal confidence between the manufacturer and user, which could not indeed be too highly extolled.

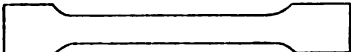
CORRESPONDENCE.

Mr. CHARLES WAWN, of the Patent Shaft and Axletree Company, Wednesbury, has contributed the following information to the discussion on Mr. White's paper :—

I have just completed a series of experiments with open-hearth basic steel, undertaken to determine to what extent, if at all, it is injured by the process of riveting. The tests were not finished when Mr. White's paper was read, but I am now in a position to place the results before the Institute.

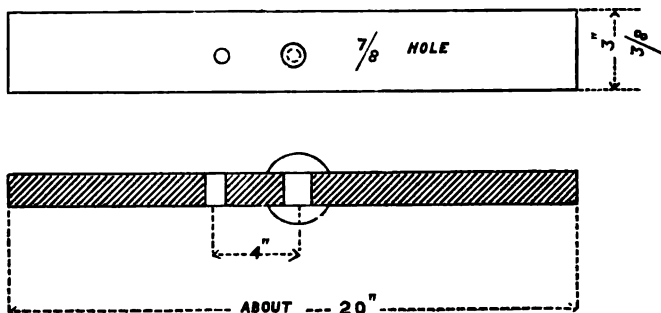
As the object of the experiments was to determine the strength of the steel itself, and not the strength of any particular description of riveted joint, one thickness of plate only was used. Altogether, one hundred and thirty-five tests were made, the samples being taken from five $\frac{3}{8}$ -inch plates, each of which was cut into twenty-seven pieces, numbered thus:—

1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18
19	20	21	22	23	24	25	26	27

The pieces numbered 2, 14, and 26 in each plate were prepared in the usual way  and tested to

get the average strength of the unperforated plate. The remaining twenty-four pieces were holed in two places. One hole was filled with a rivet put in by the hydraulic riveter, and the other hole was left open.

The following sketch shows a test-piece ready for pulling:—



The object of this form of test-piece was to show (in addition to the absolute strength of the riveted steel as compared with the unperforated plate) unmistakably, and at one and the same operation, its relative strength at two exactly similar holes, one left blank, and the other subjected to the heat and other influences incidental to the process of riveting.

The strips were sheared about $3\frac{1}{2}$ inches wide, and planed to 3 inches. The holes were drilled out. The steel was made by the Patent Shaft and Axletree Company of Wednesbury, and the tests were carried out at their Monway Works. The blooms from which the plates were rolled were from different charges.

By permission of Sir A. M. Rendel, K.C.I.E., the preparation and subsequent testing of the samples were overlooked by the Resident Inspector for Indian State Railways (Mr. C. Darke), so far as to enable him to certify as to their general accuracy.

Tables showing in detail the whole of the tests are appended. Each piece being numbered, its original position in the whole plate can be seen. This arrangement—and I am indebted to Mr. G. A. Millward, Manager of the Brunswick Works of the Patent Shaft Company, for the suggestion—supplies to some extent the information asked for by Colonel Dyer during the discussion on Mr. White's paper.

The following is a summary of the results :—

Description.	Breaking Strain in Tons per Square Inch.			Average Extension in 10 inches.	Average Reduction of Area at Point of Fracture.
	Highest.	Lowest.	Average.		
Plate A.				Per Cent.	Per Cent.
3 ordinary samples . . .	27·8	27·1	27·46	21·8	44·5
24 riveted samples *. . .	27·9	26·2	27·25	...	...
Plate B.					
3 ordinary samples . . .	28·1	26·9	27·5	24·2	51·7
24 riveted samples †. . .	28·3	26·4	27·27	...	...
Plate C.					
3 ordinary samples . . .	30·6	28·9	29·6	23·8	47·6
22 riveted samples . . .	31·1	29·1	30·17	...	...
2 riveted samples ‡. . .	29·6	29·6	29·6	...	...
Plate D.					
3 ordinary samples . . .	28·1	26·9	27·5	24·7	51·4
24 riveted samples §. . .	28·4	27·0	27·6	...	...
Plate E.					
3 ordinary samples . . .	29·3	28·7	28·9	21·2	40·7
23 riveted samples . . .	30·1	28·2	29·06	...	...
1 riveted sample . . .	...	...	29·54	...	...

* All the riveted samples broke through the open hole.

† All the riveted samples broke through the open hole.

‡ 22 samples broke through open hole ; 2 samples broke through riveted hole.

§ All the riveted samples broke through the open hole.

|| 23 samples broke through open hole ; 1 sample broke through riveted hole.

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In each case the whole plate was cut up and tested, and the results show conclusively that the strength of the net area of the plate after holing and riveting is practically the same as that of the unperforated plate.

These results, although the tests were differently arranged, confirm those obtained by Mr. White, and justify his opinion that in riveted work open-hearth basic steel is fully equal to open-hearth acid steel.

There is one peculiarity in the results which will strike every one. With the proverbial exceptions to prove the rule, the whole of the samples broke through the *open hole*, and not through that which had been subjected to the process of riveting. Although the broken samples show generally that the second hole was heavily strained and near the point of fracture, the fact remains that the riveted holes gave the best results. I attribute this to the *grip* of the rivet head on the plate behind the hole, which, although not great, may have been sufficient (the conditions being otherwise equal) to turn the scale in favour of the riveted hole. Against this suggestion it will probably be urged that the stretching under the test strain would reduce the thickness of the plate and destroy the holding power of the rivet head. This would be true of any other part of the tested sample, but it is evident that in the portion immediately behind the hole, owing to the want of continuity, there could be no tension whatever. Indeed, as a matter of fact, on gauging the pieces, I find, as I had expected, a comparative *hump* behind each hole. The abrasion on the surface of the plate caused by the draw of the rivet head is also very apparent, and proves that the grip was something appreciable.

PLATE A.

Date.	Description.	Charge	Dimensions of Test Piece.				Breaking Strain.		Extension.		Contraction.			Remarks.
			Dia-meter.	Width.	Thick-ness.	Area.	On Piece.	Sq. Inch.	Limit.	Ins.	Per Cent.	Dimen-sions.	Area.	
..	Ordinary samples, 2	..	..	2.14	.39	.834	23.25	27.87	2.0	20.0	1.68 x 25	.42	49.6	..
..	Do. do. 14	..	..	2.15	.385	.827	22.75	27.5	2.45	24.5	1.72 x 29	.498	39.7	..
..	Do. do. 20	..	..	2.17	.387	.839	22.75	27.1	2.1	21.0	1.73 x 27	.467	44.3	..
										3)65.5			3)133.6	
										21.8			44.5	
..	Riveted samples, 1	..	..	2.125	.375	.796	22.0	27.6	..	..	..	..	..	
..	Do. do. 3	..	..	2.125	.395	.899	22.5	26.8	..	..	..	..	..	
..	Do. do. 4	..	..	2.125	.395	.839	23.0	27.4	..	..	..	..	..	
..	Do. do. 5	..	..	2.115	.39	.824	23.0	27.9	..	..	..	..	..	
..	Do. do. 6	..	..	2.115	.39	.824	22.5	27.3	..	..	..	..	..	
..	Do. do. 7	..	..	2.115	.39	.824	22.0	26.7	..	..	..	..	..	
..	Do. do. 8	..	..	2.135	.385	.821	22.25	27.1	..	..	..	..	..	
..	Do. do. 9	..	..	2.115	.38	.803	22.25	27.7	..	..	..	..	..	
..	Do. do. 10	..	..	2.115	.385	.814	22.25	27.3	..	..	..	..	..	
..	Do. do. 11	..	..	2.115	.385	.814	22.5	27.6	..	..	..	..	..	
..	Do. do. 12	..	..	2.125	.39	.828	22.0	26.5	..	..	..	..	..	
..	Do. do. 13	..	..	2.105	.39	.820	23.25	27.1	..	..	..	..	..	
..	Do. do. 14	..	..	2.115	.385	.814	22.5	27.6	..	..	..	..	..	
..	Do. do. 15	..	..	2.115	.385	.814	22.5	27.6	..	..	..	..	..	
..	Do. do. 16	..	..	2.115	.38	.803	22.0	27.3	..	..	..	..	..	
..	Do. do. 17	..	..	2.115	.375	.793	21.75	27.4	..	..	..	..	..	
..	Do. do. 18	..	..	2.115	.375	.793	21.0	26.4	..	..	..	..	..	
..	Do. do. 19	..	..	2.135	.395	.843	22.25	26.3	..	..	..	..	..	
..	Do. do. 20	..	..	2.125	.390	.828	23.0	27.7	..	..	..	..	..	
..	Do. do. 21	..	..	2.115	.395	.835	22.75	27.2	..	..	..	..	..	
..	Do. do. 22	..	..	2.125	.395	.839	23.0	27.4	..	..	..	..	..	
..	Do. do. 23	..	..	2.125	.395	.839	23.0	27.4	..	..	..	..	..	
..	Do. do. 24	..	..	2.125	.395	.839	23.0	27.4	..	..	..	..	..	
..	Do. do. 25	..	..	2.115	.39	.824	22.75	27.6	..	..	..	..	..	
..	Do. do. 26	..	..	2.115	.39	.824	22.75	27.6	..	..	..	..	..	
..	Do. do. 27	..	..	2.115	.385	.814	22.5	27.6	..	..	..	..	..	

Broke through open hole.

PLATE B.

Date.	Description.	Charge.	Dimensions of Test Piece.				Breaking Strain.		Extension.			Contraction.			Remarks.
			Dia-meter.	Width.	Thick-ness.	Area.	On Piece.	Sq. Inch.	Limit.	Ins.	Per Cent.	Dimen-sions.	Area.	Per Cent.	
...	Ordinary samples, 2	...	...	2-12	39	826	22-75	27-5	10"	2-0	20-0	1-59 × 25	387	51-9	...
...	Do. do. 14	...	...	2-13	40	832	23-0	26-9	10"	2-75	27-5	1-60 × 27	432	49-2	...
...	Do. do. 26	...	...	2-15	385	827	23-25	28-1	10"	2-5	25-0	1-65 × 23	379	54-1	...
											3)72-5		3)155-2		
											24-2			51-7	
...	Riveted samples, 1	...	...	2-115	39	824	22-25	27-0	...	...	...	...	...	...	Broke through open hole.
...	Do. do. 3	...	...	2-105	39	820	23-0	28-0	...	...	...	...	...	...	
...	Do. do. 4	...	...	2-105	39	820	23-75	27-7	...	...	...	...	...	...	
...	Do. do. 5	...	...	2-105	39	820	23-25	28-3	...	...	...	...	...	...	
...	Do. do. 6	...	...	2-115	39	824	22-75	27-6	...	...	...	...	...	...	
...	Do. do. 7	...	...	2-105	385	810	22-25	27-4	...	...	...	...	...	...	
...	Do. do. 8	...	...	2-115	380	803	22-75	28-3	...	...	...	...	...	...	
...	Do. do. 9	...	...	2-115	380	803	22-5	28-0	...	...	...	...	...	...	
...	Do. do. 10	...	...	2-115	40	846	23-25	27-4	...	...	...	...	...	...	
...	Do. do. 11	...	...	2-095	40	838	22-75	27-1	...	...	...	...	...	...	
...	Do. do. 12	...	...	2-115	40	846	22-9	27-0	...	...	...	...	...	...	
...	Do. do. 13	...	...	2-115	40	846	22-7	26-8	...	...	...	...	...	...	
...	Do. do. 15	...	...	2-095	395	827	22-25	26-9	...	...	...	...	...	...	
...	Do. do. 16	...	...	2-105	395	831	22-0	26-4	...	...	...	...	...	...	
...	Do. do. 17	...	...	2-115	39	824	22-25	27-0	...	...	...	...	...	...	
...	Do. do. 18	...	...	2-095	385	806	22-35	27-7	...	...	...	...	...	...	
...	Do. do. 19	...	...	2-115	395	835	22-25	26-6	...	...	...	...	...	...	
...	Do. do. 20	...	...	2-115	39	824	22-6	27-4	...	...	...	...	...	...	
...	Do. do. 21	...	...	2-095	395	827	22-7	27-4	...	...	...	...	...	...	
...	Do. do. 22	...	...	2-105	4	842	22-25	26-4	...	...	...	...	...	...	
...	Do. do. 23	...	...	2-105	395	831	22-5	27-0	...	...	...	...	...	...	
...	Do. do. 24	...	...	2-105	395	831	22-4	26-9	...	...	...	...	...	...	
...	Do. do. 25	...	...	2-105	385	810	22-0	27-1	...	...	...	...	...	...	
...	Do. do. 27	...	...	2-095	38	796	21-75	27-3	...	...	...	...	...	...	

PLATE O.

Date.	Description.	Charge	Dimensions of Test Piece.				Breaking Strain.		Extension.			Contraction.			Remarks.
			Dia- meter.	Width.	Thick- ness.	Area.	On Piece.	Sq. Inch.	Limit.	Inch.	Per Cent.	Dimen- sions.	Area.	Per Cent.	
...	Ordinary samples, 2	...	...	2-13	.385	.820	23-75	28-9	10"	2-3	23-0	1-67 x 26	.434	47-0	...
...	Do. do. 14	...	...	2-12	.390	.826	24-25	29-3	10"	2-4	24-0	1-64 x 25	.410	50-3	...
...	Do. do. 26	...	...	2-12	.385	.816	25-0	30-6	10"	2-45	24-5	1-71 x 26	.444	45-5	...
											3/71-5		3/142-8		
											23-8			47-6	
...	Riveted samples, 1	...	...	2-105	.39	.820	24-5	29-8	...	...	...	...	...	...	Broke through open hole.
...	Do. do. 3	...	...	2-105	.39	.820	25-0	30-4	...	...	...	...	...	...	
...	Do. do. 4	...	...	2-105	.385	.831	25-0	30-0	...	...	...	...	...	...	
...	Do. do. 5	...	...	2-105	.39	.820	24-75	30-1	...	...	...	...	...	...	
...	Do. do. 6	...	...	2-105	.39	.820	25-0	30-4	...	...	...	...	...	...	
...	Do. do. 7	...	...	2-115	.39	.824	25-25	30-6	...	...	...	...	...	...	
...	Do. do. 8	...	...	2-105	.385	.810	24-5	30-2	...	...	...	...	...	...	
...	Do. do. 9	...	...	2-115	.38	.803	25-0	31-1	...	...	...	...	...	...	
...	Do. do. 10	...	...	2-115	.385	.814	24-75	30-4	...	...	...	...	...	...	
...	Do. do. 11	...	...	2-105	.385	.810	24-25	29-9	...	...	...	...	...	...	
...	Do. do. 12	...	...	2-105	.385	.810	24-25	29-9	...	...	...	...	...	...	Broke across riveted hole.
...	Do. do. 13	...	...	2-115	.39	.824	24-0	29-1	...	...	...	...	...	...	
...	Do. do. 15	...	...	2-105	.39	.820	24-5	29-8	...	...	...	...	...	...	
...	Do. do. 16	...	...	2-135	.385	.821	24-5	29-8	...	...	...	...	...	...	
...	Do. do. 17	...	...	2-115	.385	.814	24-1	29-6	...	...	...	...	...	...	Broke across open hole.
...	Do. do. 18	...	...	2-105	.38	.799	24-25	30-3	...	...	...	...	...	...	
...	Do. do. 19	...	...	2-085	.385	.806	24-75	30-7	...	...	...	...	...	...	
...	Do. do. 20	...	...	2-095	.30	.817	24-5	29-9	...	...	...	...	...	...	
...	Do. do. 21	...	...	2-145	.39	.836	25-75	30-8	...	...	...	...	...	...	Broke across riveted hole.
...	Do. do. 22	...	...	2-105	.385	.831	25-25	30-3	...	...	...	...	...	...	
...	Do. do. 23	...	...	2-115	.39	.824	25-0	30-3	...	...	...	...	...	...	
...	Do. do. 24	...	...	2-105	.385	.831	24-75	29-7	...	...	...	...	...	...	
...	Do. do. 25	...	...	2-105	.39	.820	25-0	30-4	...	...	...	...	...	...	Broke across riveted hole.
...	Do. do. 27	...	...	2-105	.385	.810	24-0	29-6	...	...	...	...	...	...	

PLATE E.

[illegible]

ON THE PRODUCTION OF PURE IRON AND STEEL.

BY COLONEL H. DYER, ELSWICK WORKS, NEWCASTLE-ON-TYNE.

A SHORT description of some experiments to produce pure iron and steel in the basic furnace will, I hope, prove to be of sufficient interest to induce others to assist in the same direction, and prepare for the chemist and metallurgist a basis for determining with accuracy the relative values of different alloys with these metals. Hitherto the study of this important branch of metallurgy has been to some extent groping in the dark, as it has been impossible to obtain reliable results when pure iron could not be readily obtained as a basis to work upon.

Although the results obtained from the following experiments have not absolutely solved the problem, they have approached so nearly to a satisfactory solution, that there is every reason to hope that success is not far distant, and that pure iron and steel may be produced at a reasonable cost.

In the first experiments the furnace was charged in the ordinary manner with pig and scrap of fairly good quality, and the charge was worked slowly, so as to keep the melted metal as long as possible in contact with the lime, care being taken to keep the slag well saturated with lime by liberal additions of limestone.

The phosphorus was reduced during the process, but the result left much to be desired in other respects.

Charges composed of from one-half to four-fifths of good scrap, and one-half to one-fifth of good Swedish pig, were then worked very quickly, and a remarkably pure iron was obtained. The following is the analysis:—

Combined carbon	.	.	.	.	.	.	.	.	trace
Silicon	.	.	.	.	.	.	.	.	·005
Manganese	.	.	.	.	.	.	.	.	trace
Phosphorus	.	.	.	.	.	.	.	.	trace
Sulphur	.	.	.	.	.	.	.	.	·015

It will be readily understood that great care and watchfulness was necessary in working these charges, as the metal was liable

to burst out of the furnace, and in point of fact did so several times without giving any warning.

Experience, however, overcame some of the difficulties, but the operation was always more or less risky.

This iron could only be forged in small pieces, even with the greatest care; it has therefore been impossible to obtain reliable results as regards its mechanical properties.

Dr. Hopkinson has kindly determined the magnetic properties of the metal, and the results of the experiments carried on by Messrs. Lydall and Pocklington, under his supervision, will probably be presented shortly to the Royal Society.

Speaking generally, it was found that the metal is more easily magnetised for small magnetising forces than any other metal hitherto tested; its coercive force is less, its magnetisation is greater, than any other sample experimented with.

The difficulties which attend the production of pure iron, added to the difficulties of working it, render it for the moment of little commercial value. I have, however, great hopes that these difficulties will, to a great extent, be overcome, and as further communications will be made upon this subject, if my hopes are realised, I will pass on to the next stage of the experiments, which had for their object to utilise ordinary scrap steel, and to produce in the basic furnace steel with high carbon and low phosphorus, and at the same time to decrease the wear and tear of the furnace.

The principle of the process consists in melting scrap with carbonaceous material, and the results of the experiments have shown that when a pure carbonaceous material and ferro-manganese free from phosphorus can be obtained, there will be no difficulty in producing a pure carbide of iron containing only sufficient manganese for forging.

On the bottom and banks of the bath of a Siemens furnace with a basic lining, a layer of coarsely broken limestone was evenly laid, and on this coke was charged; the scrap was then charged on the top of the coke, and the charge was melted down as quickly as possible.

The scrap used in these experiments averaged sometimes as much as 0.07 phosphorus and 0.03 sulphur.

The scrap, as it melted, trickled down on to the coke, which

not only reduced the oxide of iron formed in the melting, but also carbonised the steel, so that when the charge was melted the metal contained from $1\frac{1}{2}$ to 2 per cent. of carbon.

A good furnace, working well, will require about 9 cwts. of coke to 14 tons of metal.

When the charge was melted, additions of ore, manganiferous ore for preference, and limestone, were made as required, and the charge was worked in a similar manner to a charge in a silica-lined furnace, except that more limestone was used.

The amount of slag produced by this process is small, and it usually contains about 15 per cent. of ferrous oxide and 25 per cent. of silica. It has very little action on the banks of the furnace; the repairs therefore to the furnace bottom and banks are much less than when the charge is worked without coke. Indeed, the best proof in favour of the process is that it has now been eighteen months at work purifying scrap, and there has not been any attempt on the part of the metal to break through the furnace, a somewhat common occurrence in the ordinary basic process.

The amount of phosphorus eliminated during the melting of the metal varies considerably in different charges, but usually the greater part passes into the slag at this stage.

Nine consecutive charges were worked, with the object of producing steel containing varying percentages of carbon, to test the value of the process. The following table gives the chemical analyses and the mechanical properties of the steel of these charges :—

Tensile Tests.					Chemical Analysis.				
No.	Yield.	Break.	Elongation.	Fracture.	C.C.	Si.	Mn.	P.	S.
			Per Cent.						
1	14·0	22·7	44·0	F.	·11	trace	·21	trace	·030
2	14·0	23·0	41·5	F.	·10	"	·21	"	·030
3	18·0	27·5	32·0	F.	·16	·020	·40	·018	·022
4	21·0	30·0	33·0	F.	·21	trace	·39	·014	·026
5	20·0	31·2	32·5	F.	·25	·014	·43	trace	·019
6	23·0	34·0	26·0	F.	·24	·018	·50	·019	·024
7	25·0	35·4	20·0	F.	·30	trace	·38	·019	·017
8	25·0	43·2	18·5	F.	·53	·012	·54	·016	·028
9	24·0	45·3	14·5	F.G.	·50	·031	·60	·009	·026

The test ingots from which the samples were taken only weighed 10 lbs.; it is therefore probable that the mechanical results would have been more favourable if the test-pieces had been made from larger ingots.

Some of the phosphorus present in the samples no doubt comes from the ferro-manganese used, and it is probable that the sulphur might be decreased, if not altogether eliminated, if carbonaceous material free from sulphur can be obtained. Charcoal was tried, but it burns away too rapidly in the furnace, and is not itself free from sulphur.

DISCUSSION.

Mr. EDWARD RILEY remarked that he had frequently found Swedish pig iron nearly pure, and since the meeting he has extracted from his notes the following analyses :—

Silicon . . .	0·626	0·875	0·523	0·441	0·920	0·484	1·333
Sulphur . . .	0·016	0·025	0·028	0·021	0·021	nil	0·016
Phosphorus . .	0·039	trace	trace	trace	trace	0·074	0·062

Some hundreds of tons of steel slabs were manufactured for the American market at Seraing, from special white pig, in a Siemens furnace with a basic lining. The analyses were as under :—

Description.	Pig Iron.	The Steel gave		
		I.	II.	III.
Carbon	3·854	0·078	0·080	0·083
Silicon	0·333	trace	trace	trace
Sulphur	0·061	0·029	0·027	0·032
Phosphorus	0·044	trace	0·005	trace
Manganese	2·319	0·330	0·432	0·360
Copper	trace	...	...	...
Iron	92·986	...	...	...
Total	99·587	...	...	...

If selected Swedish pig had been used, no doubt better results would have been obtained.

The following is an analysis of steel made from Swedish iron in a Siemens furnace with an acid lining, for the manufacture of horse-shoe nails :—

	Per Cent.
Carbon	0·051
Sulphur	traces
Silicon	traces
Phosphorus	0·018
Manganese	nil
Iron	100·169
	100·238

Mr. Riley adds, for comparison, analyses of eight samples of Swedish bar iron of one of the best brands :—

Swedish Iron.

Description.	From Leufsta.			From Hæmatite.
	22/3/83.	4/5/83.	24/7/89.	27/7/90.
Carbon . . .	0·171	0·021	0·022	0·024
Silicon . . .	0·040	nil	0·004	nil
Sulphur . . .	nil	nil	nil	0·010
Phosphorus . . .	0·006	0·027	0·018	nil
Iron . . .	99·72	99·900	99·942	99·945
Manganese . . .	0·072	nil	0·042	traces
Copper . . .	nil	nil	traces	traces . .
Total . . .	100·009	99·948	100·028	99·979

Analyses of other Swedish brands, made March 27, 1883.

Description.	I. “oo”	II. ⓪	III. ⊕	IV. Ⓢ
Carbon . . .	0·097	0·056	0·039	0·014
Silicon . . .	0·020	0·057	0·040	0·049
Sulphur . . .	nil	nil	nil	nil
Phosphorus . . .	0·015	0·014	0·030	0·040
Iron . . .	100·140	99·898	100·002	100·002
Manganese . . .	0·057	0·108	0·057	0·057
Copper . . .	trace	Minute trace	Minute trace	Minute trace
Total . . .	100·329	100·133	100·168	100·162

Mr. G. J. SNELUS, F.R.S., referred to his paper read before the Iron and Steel Institute in 1879,* and said he was so struck with the chance of making pure iron by the basic process from the time he made the first sample in 1872, that he had over and over again urged upon their Sheffield friends, who were makers of cutlery in which the whole advantage of the material depended upon its freedom from other elements, and particularly from phosphorus, that they should turn their attention to the manufacture of pure iron by the basic process. It was a wonder the Sheffield manufacturers had never seized hold of that idea and carried it out, seeing that they went to Sweden for expensive iron when they could make the same thing from our own iron here at very little expense. The proof of that was given by the paper

* *Journal*, I. 1879, p. 135.

of Colonel Dyer. He hoped that that paper would induce other manufacturers of the highest class of materials to turn their attention to the basic process for these particular purposes.

Sir LOWTHIAN BELL asked whether Mr. Riley and Mr. Snelus had not rather gone away from the subject of the paper, which related to the production of pure iron without even a trace of foreign matter? It was rather curious that in the face of their suggested readiness to produce pure iron, the chief electrician of the Post Office had been in search of that article for the last ten years. A very minute trace of carbon in iron intended for telephonic communication was a very great inconvenience; what was really wanted there was an absolutely pure iron, and, so far as he then knew, they had never succeeded in obtaining it.

Mr. EDWARD RILEY did not think they could work absolutely pure iron. There must be a trace of carbon in it, in order to make it work; otherwise they could not draw it into wire.

Mr. SNELUS added that Colonel Dyer had shown that pure iron could not be worked, and the remarks of Sir Lowthian Bell turned on the same point. He would point out that the reason why this pure iron could not be worked was that it contained the oxide of iron which had been alluded to. He thought they had not exhausted the subject of the analysis of iron, and while they had looked for the non-metallic elements (sulphur, and so on), they had not looked for the metallic parts. As Colonel Dyer had said, there was a great deal of difficulty in determining the oxide of iron. They knew it was there, and they knew what a serious influence it had upon the metal; but, so far, they had not been able to estimate it correctly or to remove it. He was trying at that moment to work out the separation of this oxide from the pure metal, and hoped to be able to lay the results shortly before the Institute.

The PRESIDENT said that the results obtained by Colonel Dyer appeared to be exceptionally interesting. He (the President) had directed the attention of Dr. Hopkinson (who had been anxious to

make some experiments with the purest specimens of iron he could get) to Colonel Dyer's results, and had been glad to avail himself of Colonel Dyer's kindness in furnishing him with specimens. The fact that the results furnished were quite exceptional in regard to the magnetic properties exhibited, indicated that at any rate Colonel Dyer's pure iron was something not very ordinarily met with, as they might be led to believe by the remarks of Mr. Edward Riley.

Mr. J. HARDISTY said that he had been some two years ago endeavouring to make a very soft steel in the basic furnace, although he had not aimed at what Colonel Dyer was now aiming, viz., absolute purity. What they were seeking to do was to get a steel particularly soft, to be used for telegraph wires and other electrical purposes, and they got a steel so good and soft that it broke at 20·9 tons on the square inch, with 30·6 per cent. elongation in 8 inches; reduction of area, 78·2 per cent. One peculiarity of that steel, which was made from Cleveland pig, was that its limit of elasticity was very high, 16·4 tons per square inch, or about 78 per cent. of the breaking strain. He had had some experience, too, of making steels very low in phosphorus, and they had got regularly a steel with 0·01 phosphorus, and often less, when beginning with a bath containing 0·5 per cent. At times, when using pig with 2 or 3 per cent. of phosphorus, they had noticed that the phosphorus had been precipitated from the slag during the teaming of the steel, if there was any delay in running the steel from the ladle in the casting pit; and unless there was an excessively thick slag on the metal, there was generally some phosphorus thrown down by reason of the slag taking up silica from the lining of the ladle. To prevent this, he had at one time tried a basic lining for the ladle, but did not persevere with it, as other and more urgent matters were then requiring his attention. With regard to the nine tests mentioned in the paper, he thought that Colonel Dyer had forgotten to state on what length the elongation had been measured.

Colonel DYER said the length was two inches.

Mr. HARDISTY—That would be the test-piece of the Woolwich

pattern. He had made large numbers of tests of steel with that particular form of test-piece, and on the length of 8 inches, commonly used at steelworks, he found that the percentage of elongation was generally one-third more in the short piece than in the long piece. When steel was taken for the same bar, and reducing Colonel Dyer's elongations by that rule to what they would be on 8 inches for facility of comparison, he found that, on the whole, they were fairly good, with the exception of the last two tests. He had made steel from Cleveland pig iron with a breaking strain of 43 tons per square inch, and from 16 to 18 per cent. elongation in 8 inches, and Colonel Dyer's only gave 13·8, and in the last example only 10·8, per cent. elongation, which was very low. The sulphur which was shown to exist in the steels referred to was very high; but, as Colonel Dyer had explained, the bulk of that sulphur probably came from the coke. He did not know to what extent steel would take up sulphur from the gas; and he had himself mentioned at one of the Institute meetings seven years ago, that he had frequently found charges containing 0·1, or more sulphur than was calculated to exist in the charge. The phosphorus in most of the samples mentioned in the table was higher than it ought to be when beginning with such materials as Colonel Dyer has used, and with those materials as a basis, there would be no difficulty in getting both sulphur and phosphorus lower if proper attention was paid to the slag. The whole secret of success lay in proper treatment of the slag, which in the making of pure iron needed special attention, and must be of special composition. *Notes: Dyer's charge was - No slag can carry 25% silica + give pure iron.*

CORRESPONDENCE.

Mr. F. W. PAUL (of the Steel Company of Scotland) made the following remarks, through the Secretary:—About six years ago I succeeded in making a charge of steel in a basic furnace, which was very similar in composition to the analysis given on page 88 by Colonel Dyer, but its physical properties were different. I sent a sample of this steel in the form of a 1½-inch round bar to

Mr. Gilchrist, and he kindly favoured me with Mr. Edward Riley's analysis, which was as follows :—

Carbon	·018
Silicon	—
Sulphur	·007
Phosphorus	·010
Manganese	·072

The breaking strain was 23·3 tons per square inch, with an elongation of 35 per cent. in 8 inches.

I am pleased to note that Colonel Dyer expresses a sanguine hope that such pure iron or steel may be produced at a reasonable cost ; for, I must candidly admit, my experience was not in this direction. The difficulties I encountered were not what Colonel Dyer terms “the bursting out of the furnace,” but the greater difficulty of maintaining sufficient heat to enable the furnace to be tapped.

Colonel Dyer remarks further that the sample of iron was extremely red-short, or, to use his own words, “that it could only be forged in small pieces.” I am rather surprised at this, and would venture an opinion that the red-shortness was probably in a great measure due to oxygen in some form, for the steel, of which I have given an analysis, stood a high welding heat admirably, and, in a hammerman's language, forged like lead. I would remark that during the working of this charge, and some time previous to tapping, there was added at short intervals a few lumps of spiegel in order to guard against red-shortness.

At page 89, Colonel Dyer attaches importance to having ferromanganese free from phosphorus. I may say that there is no difficulty in making a special steel with practically a trace of phosphorus, as the phosphorus added by the addition of ferromanganese is trifling, and this seems borne out by reference to the experiments Nos. 1, 2, and 5, which only contain traces of phosphorus. I feel sure it must have sorely perplexed many present who have had charge of basic furnaces and Bessemer plants, to account for an occasional charge showing considerable increase in the percentage of phosphorus in the steel after teaming, as compared with the phosphorus in the bath sample or vessel sample ; and as Colonel Dyer is desirous of having a very pure steel, I would point

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out a likely source of phosphorus. It will be readily admitted that a bath of steel is more subject to waste when it is what melters term "dead off the boil," and unless the precaution was taken of adding manganese, the slag would become too highly enriched with peroxide of iron.

My remarks bear more especially on very low carbon steel, although the same thing takes place in ordinary practice, but, of course, to a less extent.

Another point I wish to call attention to is, that it is usual, in all steel works, to tap into ladles that are lined with silica material, and doubtless there are members present who have noticed that during a teaming operation the silica lining of the ladle has been greatly attacked or fluxed away. It will readily be conceived that the smaller the quantity of slag as compared with the metal, as is the case in working scrap charges, the more readily does the slag lose its basicity by the silica lining being fluxed away, which necessarily results in the phosphorus being taken up again by the metal.

In reference to the special object that Colonel Dyer has in view—that of making a pure iron or steel—I would beg to suggest as worthy of consideration the advisability of using a basic lining for the ladles.

In reference to sulphur, I have found that the presence of manganese in the bath tends to its more ready elimination, and the light thrown on this subject by the interesting communications of Messrs. Ball and Wingham, and the practice of fluxing off with manganese in the Bessemer mixer, seem to confirm the desirability of having manganese present whilst working a charge for pure iron or steel.

Mr. GEORGE S. PACKER (Atlas Works, Sheffield) remarks that, as Colonel Dyer points out, the difficulties met with when attempting to make pure iron, or steel very low in carbon, are due to a large extent to the presence of oxide in the metal, the final traces of which are very difficult to remove.

The bad effects of this oxide were recognised some fifteen or sixteen years ago by Mr. James Riley, who found this to be the cause of some tinplate material working badly at Landore. Since

then Mr. Packer has followed up the point at the Hallside Works at Mr. Riley's request. It is an evil which was recognised and carefully guarded against during the course of manufacture at the latter works from early times.

During the course of his experience, Mr. Packer has found the Bromine method (with due precautions) of estimating this oxide give concordant results, and that a good steel was not condemned by it, while a bad steel—when not due to other causes—was not allowed to pass. Generally speaking, he has found steels (his experience hitherto has been with Siemens steel; he does not, therefore, refer to other kinds) with a percentage of $\cdot 02$ to $\cdot 05$ per cent. as determined by this method, to work well throughout, while with an amount of $\cdot 10$ per cent. the steel, although not absolutely bad, was not what it ought to be; its good qualities were impaired, and in some cases, where the steel had been allowed to pass out for the more important kinds of work, led to complaints of the metal being made. This statement would, of course, require some modification, in accordance with the amount of other impurities present.

Mr. Packer had dealt with a large quantity of steel for the purpose of separating this oxide, and making an analysis of it, and found it to be, not an individual oxide, but oxides of silicon, iron, and manganese, in somewhat varying proportions. Some that were separated from acid Siemens steel have shown :—

Silica	11.8	12.0
Oxide of iron	59.6	77.0
Oxide of manganese	28.0	11.0

Other analyses had shown a larger proportion of manganese, and a smaller of iron than these. Some from basic Siemens steel had shown :—

	Per Cent.	Per Cent.
Silica	35	32
Oxide of iron	43	45
Oxide of manganese	21	22

The basic steels here referred to contained between $\cdot 02$ and $\cdot 03$ per cent. of oxide and slag, comparing very favourably in this respect with acid steels.

Mr. Packer should like to ask Colonel Dyer whether, in making

the pure iron he refers to, containing only traces of manganese and carbon, he has used any deoxidant such as aluminium or sodium?

Mr. ALEX. E. TUCKER submitted the following remarks:—As interesting to those concerned in the relative merits of the basic Bessemer and basic Siemens processes, and, at the same time, marking what is really an epoch in the progress of the basic process, I may state that I have before me the examination of some steel made by the Staffordshire Steel Co. The results of my analysis are that there has been made in considerable quantity, and in the basic Bessemer converter, steel containing—carbon, 0·04; silicium, a trace; phosphorus, *nil*; manganese, 0·10; and sulphur, 0·01 per cent. I believe this result has seldom or never been obtained in the Siemens furnace, except, perhaps, accidentally. And when it is remembered that, by certain modifications, these results can be obtained in the basic converter, I think it well to put on record so distinct an advance on what are ordinarily considered as the limits of purity in commercially made iron—the more so as, while the iron described by Colonel Dyer was largely unworkable, that made at the Staffordshire works worked perfectly in every test to which it was subjected. As regards the interesting result mentioned by Sir A. Hickman as showing the advantage of introducing the ferro by means of a wooden box, it would appear to me that the merits of that system largely depend on the addition of the carbon used. This would, of course, remove much of the oxide present in the metal, and therefore less ferro will be required; thus less is consumed, and less manganese need be present in the finished metal.

Colonel DYER, in reply, said he was much obliged for the manner in which the members had received his paper. Mr. Edward Riley had been fortunate enough to get pure Swedish pig. He himself had never met with it. He had never seen Swedish pig iron with less than 0·018 of phosphorus. He thanked Mr. Snelus for the interest he was taking in the subject of removing oxide from steel, because he regarded it as an impurity only second to phosphorus. All the experiments that he had carried out proved to him that there was a great deal more to be learned

about the presence of oxygen in steel than they had ever yet dreamt of. He found that where steel contained a larger quantity of oxide—he could only guess at the quantity, but he had reason to believe it contained large quantities—it emphasised the other impurities in a remarkable degree, and if they could only purify it sufficiently to get rid of the main portion of the oxide, he had no doubt they would overcome one of the great difficulties which now presented themselves in the regularity of basic steel. The tests which he had given in his paper should not be looked upon as giving results with a view of showing any particularly good qualities in the steel. The nine tests were made simply as an experiment, to see how close they could work for carbon in that process. They were made with a view of purifying scrap, because they did not use basic steel for anything except purifying scrap. All the gun steel was made in the acid furnace. The tests referred to in the paper were taken from small ingots made in a hand-mould held under the ladle while it was being run out, merely to get an idea of the quality of the steel.

The PRESIDENT said he was sure the members would desire to convey their hearty thanks to Colonel Dyer for his interesting communication, and to express a hope that before long, probably by that time next year, they might receive another communication from him in the same direction.

EXPERIMENTS ON THE ELIMINATION OF SULPHUR FROM IRON.

BY EDWIN J. BALL AND ARTHUR WINGHAM.

THE experimental removal of sulphur from pig iron is not attended with that prospect of impossibility which for so long has been attached to it. The difficulties are practical ones, for in the laboratory the sulphur can with ease be completely removed. Practical methods are now being established, and as any information on the subject is of interest, we place before the Institute the results of some experiments which were made about four years ago, and which led in 1888 to an application for patent rights. Probably the nature of the investigation is already familiar to some of the members of the Institute. A few experiments were carried out at the Brymbo Works at the suggestion of Mr. Gilchrist, with a view to combine desulphurisation with the Darby recarburisation process, but they were not satisfactory, and the subject was not pursued. All the rest of the experiments were made at the Royal School of Mines in the laboratory of Professor Roberts-Austen, to whom we are much indebted for the valuable assistance he afforded us throughout the progress of the investigation.

In the laboratory, after trying various unsuccessful means to reduce the sulphur, it was found that potassium cyanide placed on the surface of molten cast iron almost completely removed the sulphur. The following results fully demonstrated this fact:—

Experiment.	Metal.	Potassium Cyanide.	Sulphur per Cent.	
		Grains. Large excess	Before.	After.
1	Grains. 2000		0·72	0·007
2	2000	1000	0·46	trace
3	6000	500	0·46	trace

Owing to the extreme volatility of the cyanide, it was not found possible to reduce the quantity required to within practicable limits, and efforts were therefore made to find some flux which would retain, when molten, a quantity of cyanide sufficient to effect the desulphurisation. Sodium carbonate, lime, and blast-furnace slag were in turn tried. It was found that the desulphurising action was greater when the flux consisted mainly of sodium carbonate than when a less basic lime slag was used; and, further, that in the latter case the diminution in the percentage of sulphur varied directly with the amount of added cyanide. This will be seen from the following results:—

Experiment.	Metal.	Blast-furnace Slag.	Lime.	Sodium Carbonate.	Potassium Cyanide.	Sulphur per Cent.	
	Grains.	Grains.	Grains.	Grains.	Grains.	Before.	After.
4	2000	500	50	...	100	0·72	0·54
5	2000	500	75	...	300	0·72	0·36
6	2000	(350 glass)	50	...	500	0·72	0·25
7	2000	...	150	500	600	0·46	0·08
8	2000	...	...	200	100	0·46	0·06

These last experiments showed the superiority of the soda flux, and they also showed that the addition of cyanide in large excess was useless, probably owing to the waste due to its extreme volatility.

These results led to the following experiments, made with a view to ascertain what would be the action of sodium carbonate alone, no cyanide being added:—

Experiment.	Metal.	Sodium Carbonate.	Sulphur per Cent.	
		Grains.	Before.	After.
9	6000	100	1·11	0·52
10	6000	200	1·11	0·19
11	4000	400	1·11	0·17
12	4000	400	1·11	0·15

In order to ascertain whether repeated treatment with sodium carbonate would further reduce the percentage of sulphur, the metals from experiments 10, 11, and 12 were separately remelted with fresh quantities of carbonate. The following were the results obtained:—

Experiment.	Metal.	Sodium Carbonate.	Sulphur per Cent.	
			Before.	After.
13	Grains 2230	Grains. 100	0·19	0·15
14	3100	400	0·17	0·13
15	3500	350	0·15	0·16

There was practically no diminution. Apparently sodium carbonate alone would not completely remove the sulphur. When, however, a mixture of it with potassium cyanide was used the results were much more satisfactory, as the following show :—

Experiment.	Metal.	Sodium Carbonate.	Potassium Cyanide.	Sulphur per Cent.	
				Before.	After.
8	Grains. 2000	Grains. 200	Grains. 100	0·46	0·06
16	2000	100	100	0·46	0·06
17	4000	100	Ferrocyanide 100	0·18	0·07

Ferrocyanide, which on heating yields cyanide, was used in some cases as offering a more convenient salt. It was evident from these results that the cyanide greatly assisted the action of the carbonate. The same beneficial effect was noticed in other experiments in which caustic soda was used, and which gave the following results :—

Experiment.	Metal.	Car- bonate.	Caustic.	Cyanide.	Ferro- cyanide.	Sulphur per Cent.	
						Before.	After.
18	Grains. 3000	Grains. ...	Grains. 100	Grains. 100	...	0·21	0·05
19	7000	100	100	...	25	0·19	0·05
20	6000	100	100	...	9	0·26	0·02

The reduced quantity of cyanide, in the experiments in which caustic soda was used, led us to believe that it might possibly be dispensed with altogether. The following experiments with caustic soda alone were therefore tried :—

Experiment.	Metal.	Caustic Soda.	Sulphur per Cent.	
	Grains.	Grains.	Before.	After.
21	6,000	300	0.52	0.26
22	6,000	300	1.11	0.26
23	40,000	2,000	0.72	0.12
24	2,870	300	0.15	0.02

In each of the foregoing twenty-four experiments the alkaline slag was allowed to act for about twenty minutes. A comparison of the figures of experiments 21 and 22 shows the facility with which the sulphur is removed when present in large quantity, since the same treatment reduces such varying amounts of sulphur to the same figure. No. 23 was an experiment tried on a slightly enlarged scale, and showed that the same proportion in larger bulk acted equally satisfactorily. Experiment 24 was an important one, as it showed that caustic soda by itself would, under certain conditions, act successfully. Previously it had appeared that the cyanogen had some direct action in removing the sulphur, but this indicated that the real agency at work was metallic sodium formed *in situ* by the reduction of the soda by the carbon and iron. This was proved by an experiment in which metallic sodium was introduced into the bath in the form of an alloy with lead. The following result was obtained:—

Experiment.	Metal.	Sodium.	Sulphur per Cent.	
	Grains.	Grains.	Before.	After.
25	4500	250	0.18	Nil.

The foregoing results are selected from a much larger number. On comparing them it is most noticeable how frequently the sulphur is reduced to about 0.15 per cent. The repeated appearance of this figure is of interest, and would appear to indicate that this small quantity of residual sulphur is in a different state of combination to the remainder. It is very remarkable that, while the bulk of the sulphur in a rich sample is readily extracted by alkali alone, this last 0.1 per cent. is not eliminated except under special conditions. It would seem from these experiments that it is then necessary to bring more powerful reducing agents into

play, so as to eliminate any oxidising agents which might be present. In the laboratory potassium cyanide was employed, and this, either by its great reducing powers, or by its facilitating the formation of metallic sodium or potassium, enabled the operation to be completed at comparatively low temperatures. At higher ones this salt would not be used at its best, on account of its volatility—a factor decidedly against its practical utilisation. Indeed, it would most likely not be wanted at all, as the alkali apparently becomes more active as the temperature increases.

Basic lime slag with soda present would not act in the laboratory, probably because the temperature was too low. At the high temperature of practical working it is probable that such a slag might become active in removing sulphur, provided, of course, that the condition as to the avoidance of oxidising influences was observed. A basic lime slag *per se*, under these conditions, might act alone, and we have evidence that magnesium-yielding fluxes can so act, although it is to some extent doubtful, as it would appear that it is not only necessary that all chances of external oxidation should be avoided, but also that any dissolved oxides of iron should be reduced. It may be considered that in molten cast iron there is little likelihood of there being any dissolved oxide present with 3 or 4 per cent. of carbon, but this is no more difficult of comprehension than the known existence of a small amount of carbon in blown metal wherein the quantity of dissolved oxide is large. Such a trace of oxide might easily exist, and might indirectly be the origin of the reluctant 0.1 per cent. of sulphur. At any rate, it would probably be found necessary to incorporate with the basic lime slag a certain quantity of soda.

Again, the tenacity of the supposed trace of oxide might render this sulphur proof even against this attack, and necessitate the employment of a still more powerful reducing agent. The only practical agent which suggested itself was, of course, spiegel or ferro-manganese. Acting upon this idea an experiment was performed, in which the cast iron was treated to the action of carbonate of soda before and after the addition of a small quantity of ferro-manganese. The experiment was successful, the sulphur being reduced by sodium carbonate alone from 0.58 to 0.14 per cent. (the same curious figure), and by carbonate in conjunction

with manganese, added in the form of a rich ferro, from the above 0.14 to 0.06 per cent.

In the face of this experiment it naturally interested us to learn that a practical process was being successfully worked out for removing the sulphur by the use of rich manganese slags. In the process at the Hoerde Works we believe from Massenez's paper,* and from more recent publications on this subject, the theory is that the sulphur is taken out by the manganese itself, and analyses of the various slags have been given. It is to be regretted that there is not more information on this point. It would be interesting to know whether so much of the sulphur is combined with the manganese in these richly manganiferous slags, as has been stated to be the case, and whether it is really the manganese which removes it from the iron, since cases are known of iron containing 2 or 3 per cent. of both manganese and sulphur. Some exception may, perhaps, be taken to the statement made by Mr. Massenez in respect to "an inappreciable portion of the sulphur of the slag being oxidised to sulphurous acid by access of air."

The experiments now described were shown to a few iron manufacturers, but none could see any probability of them leading to a practical issue. It is well known that, if it is desired to keep the sulphur low, an excess of lime and extra fuel must be used in the blast furnace, working hot. Such working gives, of course, a more basic slag, and renders the furnace conditions more reducing than they were before; but even then, substances which can exert an oxidising power are present, and the reduction is not perfect. In fact it is difficult to see how the conditions in the blast furnace could be made absolutely reducing.

The conditions necessary for the complete removal of sulphur are never obtained in the production of pig iron, nor in any of the furnaces used for its conversion into steel. It has long been known that when manganese is added to the bath of metal after the blow, it either partly removes or masks the sulphur. Now, whether this part-removal is by the action of the manganese direct, or whether it is due to the manganese producing complete deoxidation and allowing the slag to act, it is difficult to decide. At any rate, it is the first time in its manufacture

* *Journal of the Iron and Steel Institute*, 1891, No. II, p. 76.

that the metal is in the necessary condition for desulphurisation, free, that is, from oxidised compounds, and immediately the sulphur begins to come out.

It is not, perhaps, a matter of surprise that the practical experiments at Brymbo, to which reference has been made, were unsatisfactory, since in the Darby process the surroundings are hardly those which are wanted. Even in these experiments, however, with the short period of contact with the salts, there are signs of a diminution in the sulphur; but then the idea was to combine the two objects, desulphurisation and recarburisation, in the one operation. As unsatisfactory experiments are often of interest and instructive, the results, &c., are given in the form of the following report on the subject as received from Mr. Gilchrist, whose cordial assistance it is our pleasure to acknowledge:—

“Experiments made at the Works of the Brymbo Steel Company, for the Removal of Sulphur from Pig Iron.”

“In each experiment 4 cwt. of pig iron from Dowlais was used. It was melted in a small cupola, and run direct through a filter about 1 foot 6 inches in diameter by 3 feet high, having a fire-clay plate in the bottom about 8 inches diameter, containing five holes of $\frac{1}{2}$ inch diameter.

“In this filter the charcoal, coke, &c., was placed about 1 foot deep, or thereabouts. The metal ran through into a ladle underneath, from which it was subsequently cast into pigs.

“Experiment No. 1.”

“Ran 4 cwt. of 0·35 Dowlais pig through filter in which 20 lbs. of lumps of carbonate of soda, mixed with its own volume of coke, was placed. Part of metal skulled in filter.

“Sulphur in metal running from cupola . . . 0·277 per cent.

“ ” ” after passing through filter . . . 0·212 ”

“Experiment No. 2.”

“Ran 4 cwt. of 0·35 Dowlais pig through filter in which coke was placed, which had previously had run over it 10 lbs. of melted ferrocyanide. There was immense volatilisation, and some of the metal skulled.

“Sulphur in metal running from cupola . . . 0·175 per cent.

“ ” ” after passing through filter . . . 0·192 ”

“Experiment No. 3.”

“Ran 4 cwt. of 0·35 Dowlais pig through filter in which was placed a mixture of coke and 16 lbs. of lump carbonate of soda. The coke had

previously had run over it 4 lbs. of melted ferrocyanide. Some skull in filter.

" Sulphur in metal running from cupola . . .	0.226 per cent.
" " " after passing through filter . . .	0.175 " ,

"It may be mentioned in conclusion that the cupola metal was much hotter than blast furnace metal would be, but in each case the cooling action of the alkaline salts caused it to skull, although the filter had previously been well heated. Ferrocyanide, when fused to drive off the three equivalents of water, is a highly deliquescent salt, which would in practice cause much trouble.

"26th June 1889."

We trust that the publication of these results of our experiments may be useful in throwing some light on this important subject, since the practical removal of sulphur, which has until recently been classified amongst the impossibilities, is stated to be at last accomplished, although by a different means to that which we have pointed out. Of course the above figures relating to the amounts of materials used must not be scrutinised too closely as to their practicability, as the experiments were on a small scale, and the waste was necessarily excessive. The results show that under certain conditions any amount of sulphur can be readily and almost completely removed from pig iron. Those conditions are the contact of the molten metal with an alkaline or basic slag, and the necessity of having the metal and the surroundings in a perfect state of deoxidation—a basic process in direct contrast to the basic phosphorus process. Indeed, it would not be beyond the bounds of possibility to find that, if the conditions of the basic-lined converter were suddenly transformed from highly oxidising to thoroughly reducing ones, the sulphur would be removed and not the phosphorus.

The sulphur was eliminated apparently by metallic sodium with the formation of sodium sulphide, part of which volatilised while part remained in the slag. Since the sodium (or potassium) is produced *in situ*, it is obvious that the sulphur will be more easily removed from pig iron, which favours its production, than from blown metal or steel. In fact, our opinion is that it will always be found easier to eliminate sulphur from cast iron than from steel, whatever happens to be the means employed.

DISCUSSION.

Mr. JOSEPH MASSENEZ made the following observations, through the Secretary:—The laboratory experiments communicated by Messrs. Ball and Wingham confirm the observation that by the reaction of potassium cyanide on molten cast iron the sulphur contained in the latter is removed. These experiments further confirm the observation that a considerable, but somewhat less, elimination of sulphur takes place if a lower quantity of potassium cyanide is employed, and sodium carbonate is added, and that only a proportionally small amount of sulphur is removed if a part of the potassium cyanide is restored by blast-furnace slag or lime; and if such mixtures of potassium cyanide, with blast-furnace slag, or of potassium cyanide, with blast-furnace slag and lime, act on the surface of the molten pig iron. Moreover, it arises out of the experiments Nos. 19 and 20 that an extensive elimination of sulphur results by using ferrocyanide, caustic soda, and carbonate of soda. Messrs. Ball and Wingham acknowledge that these experiments, interesting as they are, give no practical way of removing sulphur economically. I think, however, that we shall attain to the removal of sulphur in a practical and cheap manner, and so completely that the steel produced from such purified pig iron shall contain no remarkable quantity of sulphur. To effect this purpose, such a method of elimination must bring the amount of sulphur in the purified pig with certainty and cheapness down to 0·05 per cent., and even less.

The authors state that by employing the reaction of alkali only so much sulphur can be removed that the last 0·1 per cent. almost wholly remains in the pig. In order to bring down the sulphur to less than 0·1 per cent. the authors treated the pig, firstly with sodium carbonate, and, in a second operation, they added ferromanganese to the pig previously purified by sodium carbonate. By the first experiment they reduced the sulphur from 0·58 to 0·14 per cent.; and by the second operation, by adding ferromanganese, they reduced the sulphur from 0·14 to 0·06 per cent. I venture to say that it would be far cheaper and simpler to remove all the sulphur by employing only the reaction of manganese on the sulphur of the pig iron.

Messrs. Ball and Wingham are mistaken in stating in their paper that the process worked at Hoerde, which has been laid before the members of the Institute at the autumn meeting in October last, depends on the use of rich manganese slags. This process, on the contrary, rests on the reaction of manganese pig iron, viz., on the reaction of manganese upon the sulphide of iron, and the manganese slags only result from this method. By the Hoerde method the sulphur is removed easily from the pig iron which contains 1 per cent. of sulphur; it is therefore not apparent how profit can be got by removing at first, by alkali, one part of the sulphur, and then, by the known and improved method, the remainder of the sulphur. The slag recovered by the Hoerde method contains all its sulphur as sulphide of manganese. A part of this sulphur is oxidised by access of air to the surface of the slag, and escapes as sulphurous acid. There is no need for any special explanation of this oxidation. By many metallurgical processes it is known that the last parts of foreign bodies are very difficult to separate from the metal. It is, therefore, not necessary to assume that the last part of the sulphur remaining by treating pig iron with sodium carbonate is not removed by reason of oxides in the metal, and that the effect of the manganese in the elimination of the sulphur is to be attributed to the deoxidising action of the manganese. It seems to me the reason is that manganese has a much higher affinity for sulphur than iron, and therefore separates sulphur as manganese sulphide.

I cannot find why it would be easier to remove the sulphur by using a basic-lined apparatus, instead of an acid lining. In doing so, only a great part of the silicon contained in the pig would be lost. The amount of silicic acid in the slag arising from the desulphurising process has no important effect on the degree of desulphurisation, as proved by numerous experiments made during last year. I give analyses of such slags obtained—I. At Hayange (de Wendel). II. At Oberhausen (Gütehoffnungshütte):—

I.								Per Cent.
SiO ₂	.	.	.	.	.	.	.	35.70
Fe	.	.	.	.	.	.	.	3.90
Mn	.	.	.	.	.	.	.	35.70
S	.	.	.	.	.	.	.	5.19

II.

FeO	6·78
MnO	45·22
MnS	19·02
Al ₂ O ₃	2·46
CaO	2·58
MgO	0·19
P ₂ O ₅	0·31

Mr. T. E. HOLGATE, Darwen, submitted the following remarks : I was much interested by the results obtained at Hoerde in eliminating sulphur from pig iron on the large scale, as described in Mr. Massenez's paper, which Messrs. Ball and Wingham refer to. These results appear to me to be both remarkable and novel, and I made two or three experiments to see if they could be relied on. I melted sulphurous pig iron with spiegel and with ferromanganese, using sufficient to give a calculated percentage of about 1·50 per cent. manganese in the product, and used no flux or slag. I found that in general the sulphur was reduced to ·06 or ·07 per cent. The only case in which this amount of manganese failed to reduce the sulphur to a low point was one in which I used pig iron containing 2·50 per cent. sulphur, and which was low in carbon and silicon. I attribute the failure to not getting the metal properly melted, and to there being considerable oxidation. I gave the results of these experiments to the South Staffordshire Institute of Iron and Steel Works' Managers in February last, and I suggested to that Institute the feasibility of desulphurising any pig iron at the blast furnace by the aid of manganese, either in the furnace itself, or outside, before running the metal into pigs. From the Hoerde results, and from the experiments of myself and others, it appears certain that sulphur can be eliminated with certainty, or at any rate reduced to ·06 or ·08 per cent., if only sufficient manganese be present to give a final amount of 1·50 per cent. or upwards, and the metal be left at rest in a molten condition for twenty or thirty minutes, so as to give time for the sulphide of manganese to separate. Although we frequently see analyses of pig iron showing high figures for both manganese and sulphur, yet if such pig iron be molten, and kept at rest as described, it will have the sulphur reduced through

the separation of sulphide of manganese. This effect takes place without the presence of any added flux or slag.

It would be interesting if Messrs. Ball and Wingham could give analyses of the cast iron used in their experiments, especially the percentage of manganese before and after. If any considerable amount of manganese was present, it may have had a material influence on the results. In the experiment described in the paper read, in which ferromanganese was used, the manganese has probably had the principal effect. I should like to ask, also, if in their experiments they used crucibles of fireclay or graphite? This would affect the conditions as to their reducing character, and might make an important difference.

The experiment with metallic sodium is to me very interesting, as it causes the removal of the whole of the sulphur. The various agents that they used in the experiments seem to be effective in proportion to the ease with which the metallic element in them can be reduced. It appears to me that in order to get the sulphur to leave the iron, some other element with which it can combine must be presented to it, not in the state of oxide, but reduced to the metallic state, or on the point of being so reduced. Hence oxides and oxidising conditions are not favourable to the removal of sulphur from cast iron. Lime only removes sulphur from iron at a very high temperature, and under strongly reducing conditions, as it is extremely difficult to reduce to metallic calcium. Soda, when in the caustic state, is much more easily reduced, and removes sulphur at a much lower temperature.

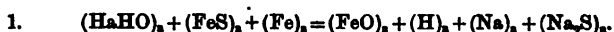
It is not an unusual thing to find sulphur completely removed in the blast furnace. Rich foundry or Bessemer iron will frequently contain only the smallest trace, whilst I do not think it possible to produce in the blast furnace spiegeleisen or ferromanganese containing appreciable quantities of sulphur.

Mr. J. E. STEAD said that a client of his had patented and worked a process based on the action of soda ash upon molten pig iron. He was sorry the inventor was not present to explain the nature of his process. He had had the pleasure of thoroughly investigating it. The result of exhaustive trials proved that sulphur was most completely removed by alkaline carbonates, so
1892.—i.

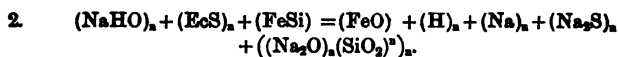
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much so that the purified metal only contained traces ; there was no difficulty in removing the last portion, or rather the 0.10 per cent. which had given Messrs. Ball and Wingham such trouble. The reason for the differences between the results of his client and those of the authors of the paper were explained when they knew that the former used a much more perfect method of mixing the soda ash and pig iron than was used in the latter. It was believed that the soda was reduced, as dense flames of sodium vapour burned at the mouth of the converter, and sodium sulphide was found in the slag. From those data it was assumed that the metallic sodium was responsible for the removal of the sulphur. It was also proved that oxidising agents might be present, such as oxide of iron, and yet most perfect elimination of sulphur result. It might be quite possible that under the conditions worked by the authors the more readily reducible cyanide effected the more perfect elimination. What his friend had proved was, that soda ash, under practical conditions, was quite as efficacious. The results of the authors themselves proved that oxidation and desulphurisation go on at the same time. In proof of this, let them notice the experiments Nos. 23 and 24, and the remarks below—" This indicated that the real agency at work was metallic sodium formed *in situ* by the reduction of the soda by the carbon and iron."

Now, when the reduction of an oxide is effected, something must be oxidised ; the soda admitted by the authors to be reduced by the iron and carbon must necessarily be oxidised, producing, as one of the products, oxide of iron. He had proved that on treating iron containing silicon not a trace of carbon was removed by soda, so it might be assumed that, in the trials Nos. 23 and 24, oxide of iron and silica must have been produced, and no carbon oxides. The reaction which took place when caustic soda was brought into contact with molten iron was most probably as follows:—



and



Judging from those facts, they must conclude that there was no need to have absence of oxide of iron in order to effect a most

perfect elimination, and that the authors' theories about traces of oxides interfering with the reaction must be considered as not in accordance with the facts. Experiment 25 was a most ingenious one, and scientifically demonstrated that metallic sodium would remove sulphur from iron. The cost of soda and other alkali salts was much against their practical application on a large scale, and it was doubtful whether they ever would be used to any extent in the metallurgy of iron and steel. The authors regretted that there was not more information regarding the changes which took place when desulphurisation was effected by manganese. If they would turn to the discussion on Mr. Massenez's paper, they would find experiments described, which were made by himself at Middlesbrough, proving and confirming exactly the statements of Mr. Massenez as to the nature of these changes, on a practical scale; the sulphide of manganese, as soon as it rose to the surface of the metal, was more or less oxidised by the atmospheric air, so that the slag eventually contained more oxide than sulphide of manganese. The sulphur passed off as sulphurous acid or dioxide.

Since the last meeting he had been to Hoerde, and had most thoroughly examined and tested Mr. Massenez's process, and had reported on it to the effect that what had been stated by that gentleman was substantially correct.

Mr. G. J. SNELUS, F.R.S., said the remarks he had made about the removal of oxide of iron were also connected indirectly with the removal of sulphur. This was an exceedingly good paper, and there were points in it which probably had more in them than upon a cursory examination of it many present would be likely at once to draw a conclusion from. With regard to the elimination of sulphur and phosphorus from iron, he did not think it had ever been sufficiently understood what were the fundamental conditions of those elements and their affinities. He had over and over again pointed out that phosphorus became fixed as phosphoric acid, and that therefore it could be fixed in an oxidising atmosphere. It was that fact which long ago drew him to the idea of the elimination of phosphorus altogether. But, under an oxidising influence, it must be associated with some body like lime, which, when it was laid hold of, would hold it firmly.

But when they came to sulphur, the conditions were entirely reversed. It appeared that sulphur was more firmly held in combination when it was formed as a sulphide; not as an oxidised product, as in the case of phosphorus. Therefore, in the blast furnace, which is a thoroughly reducing process, they had very little difficulty under proper conditions in removing the bulk of the sulphur, because they had there a reducing atmosphere which would present calcium or sodium in the reducing state, and the consequence was that the sulphur seized hold of those elements and passed out into the slag as sulphide of calcium or sulphide of sodium; and they all knew that when it became exposed to the air, they would get sulphurous acid and sulphuretted hydrogen passing into the atmosphere. Under proper conditions manganese would carry off the sulphur; but he would like to point out that manganese was not a sufficiently strong body to hold the sulphur as it should be held, and that an alkali, as, for instance, calcium or sodium, was likely, as had been shown in the paper, to hold the sulphur in the stronger bond of union, provided the conditions were right for the purpose. That was to say, that the conditions must be those of a reducing atmosphere, whereas, in the case of phosphorus, the conditions must be those of an oxidising atmosphere.

Mr. Stead had taken exception to that, and he must beg to differ a little from him there, by saying that the sulphur was removed in an oxidising atmosphere because oxide of iron was present. But he would point out that oxide of iron was not an oxidising body at all; it was a fixed body, and it would not take up more oxygen. Therefore the conditions were not those of an oxidising atmosphere at all. He did not say that it was an advantage to have the oxide of iron. On the contrary, he thought it was a disadvantage. But because that was present, it did not follow that the sulphur could not be removed, for the reason that the oxide was not an oxidising body. In order to remove the phosphorus there must be an oxidising atmosphere, and if it was desired to remove the sulphur, they must have a reducing atmosphere.

The PRESIDENT said that was what Mr. Stead had endeavoured to convey.

Mr. STEAD said that was so. If he said "atmosphere," he meant oxidising conditions.

SIR LOWTHIAN BELL said it was well known that peroxide of iron was a highly oxidising substance. There was no difficulty in washing away almost the whole of the phosphorus from pig iron, by preliminary oxidation by means of oxide of iron. With regard to the more occult chemical actions, they had still some little to learn. Mr. Stead, who always spoke with caution, had said that he recognised indications of sodium, in experiments tried at Middlesbrough. He should like to know if such appearances could be relied upon. He did not deny that sulphur might be united with sodium; but *non constat* that there was sodium. It would probably be admitted that sulphur might well be removed from iron without sodium having had a separate existence. The very substance of which so much was made in the interesting communication just read, they had in considerable quantities in blast furnace gases; he meant cyanide of potassium. He imagined that this might be due to a previous formation of sodium. He accordingly had aspirated a quantity of the gases from a blast furnace through mercury, in the hope that, if there was any free sodium present, it would be arrested, and form an amalgam with the mercury. All that he could say was, that after repeated experiments he had failed to detect metallic sodium as having been arrested in the mercury. Possibly the quantity was so small that although it was in the mercury, he was unable to detect it.

MR. E. P. MARTIN (Dowlais) said that in the works with which he was connected, they had for a long time been in the habit of using what might be termed semi-spiegel for the purpose of removing sulphur. They took care that the pig iron, after it was mixed with the semi-spiegel, contained about $1\frac{1}{2}$ per cent. of manganese, and the result generally was that they reduced the sulphur in the original pig iron as high as '1 to '6. In that way they had got rid of a large amount of Bessemer pig iron that under ordinary circumstances could not be used for certain purposes. With regard to the question of sulphur being found with manganese, they had found as much as '4 per cent. of sulphur in

pig iron containing 5 or 6 per cent. of manganese. They had tried the same material to remove sulphur from Bessemer pig iron, and found that it did not interfere at all with the removal of the sulphur.

Mr. R. A. HADFIELD (Sheffield) wished to express his thanks to the authors for their interesting paper. It was of great importance to obtain pure material, and he considered it rather a blot upon the steel trade that so much pure material had to be imported. He believed that the value of the amount now imported from Sweden, for example, was £1,000,000 per annum. He hoped that English manufacturers would now turn their attention to that point, and offer a pure material to the Sheffield steel makers. There was a nucleus of an important trade there. He should like to ask Dr. Ball, with reference to his remarks on p. 103, how he added the sodium. He (Mr. Hadfield) had tried one or two experiments in this direction, and the result had been such a pyrotechnic display that it was impossible to get the men to repeat the experiment. Dr. Ball had referred to a residual form of sulphur which had remained behind most pertinaciously.

It was rather curious that he (Mr. Hadfield) had noticed a similar effect with regard to manganese steel made at his firm's works, Sheffield. Notwithstanding the high percentage of manganese present, some 12 to 13 per cent., the sulphur is not reduced as might be expected, and seldom fell below .08 per cent. This was singular, seeing the results obtained by Mr. Massenez in his purification of pig iron by means of the addition of manganese. Mr. Martin had also stated the remarkable fact, confirming his (Mr. Hadfield's) opinion with regard to manganese steel, that he had manganiferous pig iron with .4 per cent. of sulphur. Possibly, it might be owing to the trace of oxide to which Colonel Dyer had referred. Dr. Ball had mentioned the matter on p. 106, and had pointed out that the traces of oxide might be indirectly the cause of the retention of .10 per cent. of sulphur. He should like to see the question taken up by chemists. It was for them, and not for steel makers, to show some way of determining the oxide of iron if it was present. Colonel Dyer seemed to think that it was of great importance, and no doubt it would be of considerable

advantage to prove its actual presence. He hoped that some of their chemical friends would carry out experiments in that direction.

Mr. E. A. COWPER said that over forty years ago he was innocent enough to think that possibly the quality of Swedish iron was due to the presence of potassium (from the potash in the wood fuel), or that potash had been present, and had been useful in purifying the metal from sulphur in particular. He had tried an experiment in a puddling furnace, introducing a certain quantity of soda in the form of "physic," and it certainly yielded better iron. The experiment, however, was cut short, because, when the foreman found out what he was doing, he said he had a better "physic" than Mr. Cowper's, and there was an end of it. But there was no question as to the superiority of the iron.

Mr. JAMES ROBERTS wished to say a few words with regard to the elimination of sulphur from cast iron. At the meetings of the Institute, a great deal of time was occupied in the discussion of steel. He did not deny that steel was a most important metal, affecting the interests of the country, but he might be permitted to mention an experiment or two which he had conducted in order to try and eliminate an amount of sulphur in cast iron that was detrimental to the users. Laboratory experiments were intensely interesting, but, in order that they might be of any benefit to manufacturers, they should be carried out in a practical manner, so that, after the sulphur was eliminated, they could have the iron in a state, as regards the temperature, in which it was required to make castings perfect. He had melted down in a reverberatory furnace twenty-five cwt. of iron. When it was melted, he took a test, and the analysis was: combined carbon, 2.0946; graphitic carbon, a trace; phosphorus, .371; sulphur, .214; silicon, 1.04; manganese, .3. He then added to the furnace a sufficient quantity of manganese to give about 1.2 per cent. of manganese in the result. He let it stand perfectly quiet in the furnace for twenty minutes, and then took a further test. The result was that the combined carbon was 1 per cent.; graphitic, 1.92; phosphorus, .352; sulphur, .093; the silicon had altered very little—1.376; and

manganese, '9. He then let it stand another ten minutes, and made a further trial, the result being: combined carbon, '925; graphitic, '20; phosphorus, '34; sulphur, '08; silicon, 1'376; manganese, '7. In addition to eliminating the sulphur from the iron, he also wished to try what was the result upon the strength, and upon the chill which proceeded from the different samples; and he found that in the iron as melted they had the chill white all through, but, after the addition of the manganese, the chill went down to only $\frac{3}{4}$ thick, with a perfectly grey back; and, after a further ten minutes, the chill was reduced to $\frac{3}{8}$, with a still darker and greyer back. The result in the transverse test was that in the No. 2 trial it went up $3\frac{1}{2}$ cwt. on the bar, and No. 3 broke defective, so that there was no chance of seeing how it was; the deflection went from '25 to '35. That proved conclusively to his mind two things—that the amount of sulphur which they had in the iron melted, '214, was highly detrimental to the maker of cast iron, and that the elimination of the sulphur to a point at which they could safely deal with it was perfectly practicable by the addition of 82 per cent. ferromanganese, in suitable quantities, at a small cost of 2s. 6d. per ton, and that this increased the breaking strains, and also the deflections. He proposed to continue the experiments on a much larger scale, to see what the final results would be. What he had mentioned was sufficient to show that, whereas the experiments described in the paper, which were very interesting, and for which they were much indebted to the authors, were, to a certain extent, laboratory experiments, it was perfectly practicable, without the addition of the expensive volatile materials referred to, to remove the sulphur from the iron, so far, at least, as founders were concerned.

Mr. J. HARDISTY said that at p. 109 the authors had spoken of the removal of sulphur from iron by a basic lime slag and soda, and he had also mentioned that possibly the basic lime slag would by itself remove the sulphur from iron. He had had some experience of the removal of sulphur from iron during its conversion into steel in the open-hearth basic furnace. They had some white hæmatite iron containing '22 per cent. of sulphur, which had to be converted into steel. After some trials, it was found that they

could reduce the sulphur to $\cdot 06$ per cent. by the use of lime only. Sometimes they used soda, and on other occasions fluor spar, as a flux; but although these were useful in thinning the slag, and enabling them to work a little more conveniently, they did not affect desulphurisation at all. The authors had also remarked that there must be an alteration in the condition of the sulphur when it came to about $\cdot 15$ per cent. He (Mr. Hardisty) had not observed that before reading the paper; but since then he had been looking at his notes on desulphurisation, and found that it required nearly twice as much lime to get out each unit of sulphur below $\cdot 15$ per cent. as was required to reduce it to $\cdot 15$ per cent. The sulphur was always reduced in the basic process. Starting with hæmatite containing $\cdot 03$, there would be from $\cdot 01$ to $\cdot 015$ per cent. of sulphur in the steel. Starting with Cleveland pig containing $\cdot 07$, the resulting steel would contain $\cdot 04$ to $\cdot 05$; with Cleveland pig containing $\cdot 10$, the resulting steel would contain $\cdot 06$ to $\cdot 58$; and with Cleveland pig containing $\cdot 15$ per cent. of sulphur, and without taking any pains to remove the sulphur, there would be from $\cdot 10$ to $\cdot 12$ per cent. in the steel. This amount of desulphurisation always takes place while reducing the phosphorus. He did not for a moment believe that an oxidising condition or atmosphere was favourable to the reduction of sulphur. But it was a proved fact that during dephosphorisation some sulphur was always removed. If, however, it was necessary to use a pig iron containing a large amount of sulphur, they were as careful as possible not to oxidise the charge any more than could be helped during the melting, so as to favour the removal of sulphur from the metal to the slag. It will be remembered that a paper was read at a previous meeting on M. Rollet's process* for the reduction of sulphur in a cupola supplied with hot blast, and it was stated by Mr. Hugh Bell in the discussion that at Clarence, in a chromelined cupola supplied with cold blast, the sulphur in Cleveland pig was reduced from $\cdot 08$ to $\cdot 013$ in presence of a lime slag. Sulphur in cast iron could also be reduced by casting it on a bed of finely powdered ore and lime, but the results are very irregular. During a few experiments that he had seen made, the sulphur had been reduced from $\cdot 11$ to $\cdot 07$, from $\cdot 10$ to $\cdot 016$, and from $\cdot 16$ to $\cdot 029$, but at other times the results were not so good.

* *Journal*, No. I. 1890, p. 157.

Dr. E. J. BALL said that it was difficult to reply off-hand to a discussion which had been so wide. It would be interesting to Sir Lowthian Bell to know that his experiments on the formation of potassium cyanide in the blast furnace were those which finally led to the experiments which he (Dr. Ball) had described. Mr. Wingham and himself considered in the first place what were the conditions in the blast furnace under which sulphur was eliminated from iron. They saw that it was evident that those conditions were conditions under which the formation of cyanogen, or cyanide compounds, was most likely to occur. That led them, after a number of other experiments, to try cyanide, which, however, they had to abandon. Of course the use of alkali and the use of manganese were really as old as the hills. He agreed with Mr. Stead that under such conditions as using the Bessemer converter at the temperature he employed it was likely that sulphur would be eliminated.

Mr. STEAD—It was not a Bessemer but a fixed converter.

Dr. BALL asked what was the temperature?

Mr. STEAD said it was the temperature of cast iron in the blast furnace.

Dr. BALL said that that was much higher than they had used. They had several times pointed out in the paper that they concluded that if the temperature could be raised, the conditions for desulphurisation became more and more favourable. As regarded the elimination of sulphur and the oxidation in the Hoerde process, no doubt they could smell sulphurous acid. That was the result of secondary desulphurisation of the slag, not of the iron. With regard to the question whether in experiments 23 and 24 the condition was an oxidising or a deoxidising one, he was still of opinion that it was deoxidising and not oxidising. No doubt oxide of iron did form to a slight extent, but it was on the surface of the metal. It would be immediately reduced by any silicon that was present, and the silica would pass into the slag, and then it would be without any oxidising action, and there would be an

excess of a reducing agent, not of an oxidising one. He did not like to enter into that question deeply, because he only had a moment to consider it; but he was still rather of opinion that it was a deoxidising, and not an oxidising action. As to the question whether a graphite or a silica crucible was best, they used both, and they were equally efficacious. With regard to the way in which they put sodium into iron, he confessed that there was usually a great pyrotechnic display, the sodium boiling off very rapidly.

MR. ARTHUR WINGHAM sends the following written communication in reply to the discussion:—

I very much regret that I was prevented by illness from being present at the reading of the paper. In respect to Mr. Stead's remarks, I should hardly be satisfied that a yellow flame at the converter's mouth was a proof positive of the formation of metallic sodium. Of course, we know that molten iron in contact with soda does produce metallic sodium vapour, but carbonic oxide, loaded with volatilised soda, might burn with a yellow flame difficult to distinguish from the combustion of sodium itself.

I quite agree with Sir Lowthian Bell as to the possibility of removing sulphur from iron without the actual formation of free sodium at all, that is to say, by reaction. Mr. Stead's reasoning in respect to oxidation and desulphurisation going on simultaneously is very logical, and it need be pursued but a stage further to prove that a process of oxidation should be called a process of reduction, or *vice versa*, and that the term "desulphurisation" is incorrect, because something else is becoming sulphurised. The indestructibility of matter is well understood by us, but so far as my knowledge goes the above terms are generally applied as a result of the effect on the substance under consideration or the balance of conditions in favour of either one side or the other. Mr. Stead seems to fail to see any difference between the influence of oxide of iron dissolved in the metal and that which has been freshly formed on the surface and melted with the slag.

As regards the 0.1 per cent., we contend that probably on a larger scale this, and other little difficulties that we experienced would not exist, and the fact that others have not noticed it

simply shows that the conditions of their experiments were not the same as ours. It occurred in our case, and is evidence that when the process is conducted at low temperatures the reducing conditions appear to be a necessity, indirectly showing that the same conditions would most likely be necessary at the higher temperatures.

Mr. Stead's assumption about oxide of iron alone being produced in our experiments 23 and 24 is not supported by his own experiment as he suggests, unless he proved that the percentage of silicon in his iron remained stationary, as well as the carbon. In the converter silicon is oxidised before carbon, and consequently may be assumed to be a more ready reducing agent, which quality it would probably assert on the soda to the exclusion of any action by the carbon.

Mr. Snelus refers to the reduction of the sulphur in the blast furnace, which is, of course, effected by an excess of lime and fuel. The question might reasonably be asked, Could not these excesses be more profitably employed outside the blast furnace by being allowed to act on the metal under conditions suitable for removing the sulphur? Mr. Hardisty says that he has reduced sulphur to 0.06 by lime only. This supports us in our conclusion from the laboratory experiments, that at the high temperature of practical working, a lime slag might become active in removing sulphur provided the reducing condition was absorbed.

Mr. Roberts mentions the expense of the materials referred to. Surely lime is not considered a very expensive material, and if its sulphur-removing power be augmented by the incorporation of a small quantity of soda, the cost of that soda would probably be within practical limits, especially if there was a saving in materials in other ways—say, for instance, by a reduced quantity of lime in the blast furnace. Soda by itself would be expensive, not only on account of its costliness, but because of the large waste attendant upon its use. It must not be supposed for one moment that we advocate the idea of the practical use of cyanide. This material has been useful in aiding us to form our conclusions as to the conditions required. What we do advocate is this, that lime with its desulphurising power, increased by admixture with a little soda, could probably be successfully employed in the prac-

tical removal of sulphur from iron, provided the method of application was properly studied and carried out.

The PRESIDENT said the members were much indebted to Dr. Ball and to Mr. Wingham for the care with which they had conducted their interesting experiments. Although laboratory experiments might not always in the first instance appear to accord with those obtained in practice, they ought to make due allowance for the differences as to temperature and other conditions which he was sure Dr. Ball would admit might make great differences between the result of a scientific experiment and the result likely to be obtained in practice. He proposed a vote of thanks to the authors of the paper.

WEDNESDAY, MAY 27TH.

The proceedings of the Institute were resumed to-day at the Institution of Civil Engineers, London—Sir FREDERICK ABEL, K.C.B., F.R.S., &c., again occupying the chair.

The following paper was read:—

ON THE MANUFACTURE AND APPLICATION OF CHILLED CAST IRON (GRUSON'S SYSTEM).

BY E. REIMERS, DIRECTOR OF THE GRUSONWERK, MAGDEBURG.

ALTHOUGH Gruson cannot be called the actual inventor of chilled cast iron—as the fact that iron cast into metallic moulds hardens on its upper surface was not only known long ago, but had also been used for industrial purposes in England and America for a number of years—it cannot be denied that he was the first who, after long and troublesome experiments, succeeded in producing a material, by mixing several kinds of German pig iron, and by employing a suitable process of casting, which, as far as hardness and toughness are concerned, was infinitely superior to cast iron, and suitable for the production of excellent chilled cast iron. He also found out the present very numerous and extensive modes of employment for his metal.

Hermann Gruson founded, on the 1st of June 1855, under the name “H. Gruson, Buckau-Magdeburg,” a shipping wharf on the banks of the Elbe, connected with which were small machine-works and an iron-foundry. Although the latter was, at the commencement, only of minor importance, it nevertheless formed the foundation for the future great development and present flourishing state of the establishment, which, in the year 1886, was converted into a limited company under the name “Grusonwerk,” the chief management of which was retained by Gruson until his retirement in July 1891.

In his small foundry, Gruson continued the trials he had already previously made for the manufacture of refined cast iron of great hardness. In opposition to the old process, he strove to obtain a method which would make his material quite independent of the irregularity of the blast furnace, and secure uniformity, even in cases of difference in the qualities of the iron ores employed.

In order to attain this, he had to give up using the iron in the way it was produced in the blast furnace, and gave his attention to the mixing of various kinds of iron.

The pig iron which at that time gave the greatest guarantee of being free from all prejudicial admixtures was that made with charcoal, and it was this kind which Gruson used in his experiments, and later on in the production of castings.

In order to produce metal suitable for casting in chills, he mixed white and grey charcoal iron—two kinds, of which the former is known to be as hard as steel, and brittle, containing all its carbon combined, whereas in the latter, which is soft and comparatively tough, about 80 per cent. of the carbon is separated off in scales of graphite. This mixture was, and is still, melted down by the "Grusonwerk" solely in cupola furnaces.

The proportions used in mixing depend upon the depth of hardness which the metal is to receive on being cast in a chill. The latter effects a sudden cooling down of the cast metal, and prevents thereby a large percentage of the carbon separating off in scales of graphite, so that it remains bound in the layers of the chilled casting. A layer of white iron is thus formed on the exterior, which gradually passes into grey iron. The transition between the two layers consists of mixed iron.

On examining a section of a chilled cast iron bar, the excellence of quality of the material employed is perceivable, even to the inexperienced. In good chilled iron the exterior is of a fine fibrous character, which passes without visible lines of separation into the granular structure of the so-called mottled iron, which, in turn, gradually assumes the character and fine crystalline structure of soft grey iron. If, on the other hand, the fibrous layers end in a visible line, it is certain that the casting is not a success, and that it possesses none of the desired qualities, as, in use, the hard layer severs itself from the soft one.

The various layers can, according to the purpose desired, be exactly regulated by the percentage of the elementary bodies employed, whereas the further success of the casting depends upon the correct dimensions of the chill.

The process which takes place during the casting in chill is sufficiently described by the above remarks, so long as we con-

tent ourselves with the facts, and do not inquire into the causes of the various stages. The laws which govern the binding or separation of the carbon from the iron are minutely given in most of the new treatises on the subject; nevertheless very much can still be done, as all explanations end in hypotheses, and all asserted facts only present new problems to the inquirer.

It is known that chemically pure iron is not used for technical purposes, but that it only acquires the valuable properties of commercial iron by other elements being added to it, which have aptly been named "constituent parts" (Ledebur), viz., carbon and silicon.

Besides these two elements, a third has to be mentioned—manganese—which is also to be found in all commercial iron, and which more easily explains the occurrences during casting.

The number of the various kinds of iron is very large, and the differences which they show in their various qualities are very considerable. These are, however, only to be ascribed to the percentages of the ingredients which form the constituent parts of the mixture. Manganese and silicon have different effects on the way in which the carbon binds itself with the iron, and to a certain extent maintains an equilibrium. Silicon prevents, up to a certain point, the binding of the carbon during the cooling of the iron, and causes it to separate off in scales of graphite. Manganese, on the other hand, neutralises part of the effect of the silicon, and furthers the formation of white iron. According to Ledebur, with 60 per cent. of manganese, there may be, besides 5 per cent. of coal, 25 per cent. of silicon, without causing the formation of graphite. The effect of silicon is, therefore, as mentioned above, neutralised by the manganese. If the silicon is taken out of molten grey iron, white iron is formed. If the manganese is taken away from white iron, or partly replaced by silicon, grey iron is the result.

As already mentioned, the graphite of the grey pig iron is only separated during the cooling of the iron, and the slower the cooling takes place the more graphite is separated. By rapid cooling down, therefore, less graphite is separated, and the influence of this accelerated cooling makes itself all the more felt, the more manganese and the less silicon the iron contains. Here there is a limit by which, on rapid cooling, white iron, and by slow cooling

down, grey pig iron is formed. It is such a mixture of iron which, when cast in chills, gives white iron on the exterior and grey iron in the inner layers. The proportions in which manganese and silicon are allowed to be present depend upon the depth of the hardness desired.

There is, in consequence, no difficulty in obtaining an iron from the foundry which can be cast in chills without any further admixtures. For the maker of chilled cast iron there is, however, this drawback, that he is then wholly dependent upon the smelting-works, and that he does not remark changes in the quality of the iron, which perhaps cannot be avoided by the works. Further, the iron must be adapted to the special purpose of the casting, and must, for instance, agree with the desired depth of hardness. The buying of a number of different brands would, therefore, be unavoidable. Under these circumstances the process adopted by Gruson of producing chilled cast iron by mixing various brands of iron appears to be the best, even if not the simplest.

The above shows that the effect of the chill on the iron can be increased or lessened according to the quantity of white or grey iron given to the manganese or silicon of the mixture. This can, however, only be done in case the producer knows his pig iron very well. Without doubt every foundry manager can form some sort of an opinion on the quality of the iron from its fracture. In the production of chilled cast iron this is not sufficient.

In the first place, as mentioned above, the quantity of graphite contained in a block of pig iron is dependent upon the slow or quick cooling down of the same, and the opinion formed on fracture can, therefore, only be of consequence when this is taken into consideration, which is not always an easy matter.

Further, it cannot be seen from the fracture whether the iron contains a percentage of manganese, which is also of influence on the formation of graphite. Other injurious admixtures, such, for instance, as phosphorus, cannot be seen from a section.

It is certainly taken for granted that phosphorus and sulphur, which, like manganese, further the formation of white iron, now-a-days only seldom appear in such quantities as to influence the quality and hardness of the iron. The producer of chilled cast iron must, however, also in this respect keep his eyes open. He

must know the properties of his pig iron better than any other founder, as he has to govern and modify the same, and an indispensable necessity for him is, consequently, the chemical laboratory.

Chemical analysis raises the chilled castings from empiricism to methodical manufacture. The overseer of the foundry, by the help of analysis, gets to know the elements of the various kinds of iron which he intends mixing, and this knowledge, combined with his practical experience, puts him in a position to determine the right percentages, in order to give his castings exactly the desired hardness. By means of analysis, the producer of chilled cast iron is, in fact, up to a certain point, independent of the smelting-works, as he is himself able to correct any differences in the composition of pig iron within certain limits, when mixing, and is thereby assured that the hardness of the iron is not eventually lessened by an excess of the total percentages of the admixtures. If the deviations are so great that their correction is difficult or impossible, the producer is advised in time by the analysis.

Another very important matter for the producer of chilled cast iron is to have a strength-testing machine. It can be seen from what has been stated that, by suitable additions of manganese or silicon, every kind of iron can be made to radiate into the chill, and become hard. Such a metal may, however, be very far from being good chilled cast iron, if it does not answer the requirements as far as its strength is concerned. It lies in the power of the foundry-man to modify the radiation of the iron as desired, but he is not able to prevent the iron from containing too great a percentage of foreign matter, which makes him, in this respect, dependent on the smelting-works. The iron-founder, instead of refining the iron, does better if he first tests the various kinds of iron in the testing-machine, and then forms his choice accordingly. Continuous controlling is, however, indispensable later on.

It may be well to make several remarks here on the inner causes of the greater or less strength of chilled cast iron, and of iron in general. As already repeatedly mentioned, a complete alloy of iron with its constituent parts is obtained only so long as the metal is in a fluid state; on cooling down, the alloy is broken up, and graphite, as well as free iron, part from the alloyed iron—

in short, there remains only a congested mass of various alloys and elements.

It is generally asserted that the strength of iron is increased by adding up to 1 per cent. of dissolved carbon, and is decreased by more than 1 per cent.*

The separating off of carbon from the grey iron would, therefore, have a good effect upon the strength of the iron, if the addition of graphite did not, at the same time, disturb the homogeneity. Notwithstanding, grey iron is stronger than white iron when subjected to shocks, and its strength increases when it is free from other elements. It is of especial importance that the iron shall only contain as much silicon as is necessary for the separating of the carbon. A maximum of strength must, therefore, exist for cast iron, which is attained by adding the right quantity of carbon and silicon, and this explains how castings in sand from a good mixture of white and grey iron always show a greater strength than those which are made up of the several raw materials. An analogy can be found in the fact that many sorts of mixed pig iron distinguish themselves from grey and white iron by superior strength.

So far the strongest iron was considered to be charcoal pig iron made from good ores, this, as already mentioned, having been solely used by Gruson for many years in making chilled cast iron. The greater strength of this iron, when compared with other irons, is easily explained by the fact that by the use of charcoal the temperature does not become so high as by the use of coke. In consequence, charcoal iron takes up a smaller quantity of foreign bodies, such as manganese, silicon, sulphur, &c., and receives, moreover, a finer grain. Both the greater purity and greater homogeneity easily explain the greater strength of the iron, in comparison with other kinds; the latter may, however, not now be looked upon as so self-evident as formerly. As regards the coarse grain of coke iron, it is known that this disappears on cooling down, after having been remelted one or more times. The strength and elasticity of the iron is consequently increased by moderate remelting. Of course this can only be continued up to a certain point, as the iron otherwise becomes harder and gradually goes over to white iron.

* See Ledebur, *Handbuch der Eisenhüttenkunde*.

The progress which metallurgy has made during recent years is well known. We are to-day able to make good steel out of ores which were formerly abandoned as useless. Under these circumstances, one need not be surprised that the superiority of charcoal iron, and of its alloys, as far as strength is concerned, is not now disputed.

Amongst the various kinds of iron, there are now-a-days several from which, when mixed with charcoal iron, alloys can be made which are at least equal in strength to those of pure charcoal iron. The former alloys are certainly not cheaper, as a rule. It is, however, of interest to find that the manufacture of chilled cast iron is no longer absolutely dependent upon charcoal iron, but can, with the help of chemical analysis and the testing-machine, go its own way.

A number of comparative tests which have been made in the Grusonwerk with bars from alloys of the most varied kinds of coke and charcoal iron have given the results specified in the table on page 133. Forty-four different alloys of iron were tested, which were partly composed of coke iron, partly of coke and charcoal iron, and partly of charcoal iron. Of each alloy four trial bars had been cast in such a way that each time two were cast together in horizontal moulds of damp sand. These bars were not worked. They had a cross-section of 1 inch. = 26.15 mm. square, and a serviceable length of 942 mm. (3 feet). These dimensions can be explained by the fact that the trials were meant to form a parallel to previous trials with bars of charcoal iron.

The trial bars are broken on a common breaking-machine, where the pressure is given by a lever on which the force is gradually increased, and of each alloy four bars are taken for testing purposes. These bars had a length of 114 mm. (4.48 inches) and a diameter of 16 mm. (0.63 inch), and were turned off in the middle for a length of 50 mm. (1.97 inch) to a diameter of 11.3 mm. or 0.44 inch (100 sq. mm. section). This form also agreed with the trials previously made with bars of charcoal iron. The tests were made on a testing-machine with a maximum pressure of 10 tons.

The following table contains several results of the 352 tests made in order to determine the transverse and tensile strength.

In the first line are given the results of that alloy which proved to be the worst; in lines 2 to 11 the results of the ten best.

FIRST GROUP.

Statement Showing the Results of Tests made in the "Grusonwerk" with Forty-four Chilled Cast Iron Alloys.

Square Chilled Cast Iron Bars, 26.15 mm. (1 inch) Thick and 942 mm. (3 feet) in Length.				Round Chilled Cast Iron Bars, 11.3 mm. (0.44 in.) Thick and 50 mm. (1.97 in.) in Length
Strength of Flexure (Transverse Strength).				Tensile Strength.
Running Number	Number of Casting.	Average Breaking Load of Four Bars, tons per sq. inch.	Average Deflection before Breaking, in inches.	Average Breaking Load of Four Bars in tons per sq. in.
1	5	15.9	0.89	6.9
2	70	29.4	0.94	13.6
3	40	30.2	0.77	13.9
4	39	28.8	0.80	14.1
5	65	28.0	0.81	14.3
6	16	27.8	0.91	14.7
7	24	28.9	0.96	14.8
8	22	27.2	0.98	14.9
9	64	27.0	0.75	15.2
10	21	30.5	0.97	16.8
11	10	29.3	0.77	17.9

In this table it will be remarked, in the first place, that the results of the tearing tests do not correspond with the breaking tests, as the bars which showed the greatest breaking resistance did not also give the highest tensile strength. At any rate, the tearing tests are the most accurate.

Among the iron alloys tried there are only three whose strength corresponds with that of charcoal iron, viz., Nos. 9, 10, and 11. A number of extension tests made with charcoal iron bars of the same dimensions varied in their results between 24.7 and 28.3 kg. per sq. mm. (15.68 and 17.97 tons per sq. inch).

Of the iron alloys 2 to 11, eight further trial bars of each were cast, 110 cm. long (100 cm. testing length) and 30 mm. (1.18 inch) square section. Of the broken pieces of these bars, cylindrical bars of 20 mm. (0.79 inch) diam. and 200 mm. (7.87 inches) length were then made.

The breaking tests, as well as the trials for extension, were made on a machine suitable for both purposes, and which was constructed for a maximum load of 50 tons.

For measuring the extension an apparatus constructed in the Grusonwerk was used, which shows the extension on 200 mm. (7.87 inches) length of the bars. The extension can be ascertained

with the help of a vernier up to the two-thousandth part of an inch (eightieth part of a mm.). The results of these trials can be seen in the following table.

Every three trial bars of the five best alloys were sent to the Royal Mechanical Technical Testing Works in Berlin-Charlottenburg, whose official communications are contained in the table below.

SECOND GROUP.

Results of the Tests of Ten Chilled Cast Iron Alloys made in the "Grusonwerk."

Square Chilled Cast Iron Bars, 30·6 mm. Thick and 1000 mm. Serviceable Length.				Round Chilled Cast Iron Bars, 20 mm. Diam. and 200 mm. Serviceable Length.		
Transverse Strength.				Tensile Strength.		
Running Number.	Number of Casting.	Average Breaking Load of Four Bars in tons per sq. inch.	Average Deflection before Breaking, in mm.	Average Breaking Load of Four Bars in tons per sq. inch.	Average Extension on 50 mm. Length, at Weights of	
					3000 kg. in mm.	6000 kg. in mm.
1	...	...	...	...	...	...
2	70	25·3	22·8	13·4	0·0134	0·0234
3	40	25·7	22·6	12·7	0·0223	0·1362
4	39	26·6	17·6	15·7	0·0971	0·3196
5	65	23·5	16·1	15·5	0·1150	0·3017
6	16	23·4	13·9	...	...	...
7	24	24·6	24·1	12·8	0·0167	0·0675
8	22	23·7	23·1	...	...	...
9	64	23·8	17·0	15·1	0·1250	0·3302
10	21	27·2	19·2	16·1	0·0162	0·1295
11	10	24·4	13·4	17·7	0·0271	0·0845

THIRD GROUP.

Results obtained at the Royal Mechanical Technical Testing Works in Berlin-Charlottenburg with Five Chilled Cast Iron Alloys.

Square Chilled Cast Iron Bars, 30·6 mm. Thick and 1000 mm. Serviceable Length.				Round Chilled Cast Iron Bars, 20 mm. Diam. and 200 mm. Serviceable Length.		
Transverse Strength.				Tensile Strength.		
Running Number.	Number of Casting.	Average Breaking Load of Three Bars in tons per sq. inch.	Average Deflection before Breaking, in mm.	Average Breaking Load of Six Bars in tons per sq. inch.	Average Extension on 50 mm. Length, at Weights of	
					3000 kg. in mm.	6000 kg. in mm.
4	39	21·0	16·5	16·1	0·1329	0·3621
5	65	25·2	17·5	18·3	0·1145	0·2005
9	64	25·5	19·2	16·4	0·1229	0·3533
10	21	20·3	14·6	16·6	0·1295	0·3679
11	10	26·2	19·0	19·1	0·1164	0·3002

In order to make a comparison easier, the tensile strengths obtained of five alloys mentioned in the three tables are as follows:—

Running Number.	Number of Casting.	First Group.	Second Group.	Third Group.
		Tons per sq. in.	Tons per sq. in.	Tons per sq. in.
4	39	14.1	15.7	16.1
5	65	14.3	15.5	18.3
9	64	15.2	15.1	16.4
10	21	16.8	16.1	16.6
11	10	17.9	17.7	19.1

The figures obtained by the Royal Testing Works are all higher than those of the "Grusonwerk," although the bars of the second and third groups were cast at the same time—that is to say, following one another, out of one and the same pan. The differences in the transverse strength may be ascribed to the fact that the Royal Testing Works increased the strain more slowly than was done in the "Grusonwerk." This is also the reason of the higher figures obtained by the Royal Testing Works as regards extension, and which, again, furnish the proof that the properties of a good chilled cast iron alloy vary considerably from common cast iron.

According to the results obtained by the Royal Testing Works, all five iron alloys, as far as strength is concerned, are suitable for chilled cast iron, and, as they radiate faultlessly when cast in chill, they can without doubt be termed satisfactory. Nevertheless, only two consist solely of charcoal iron, viz., Nos. 5 and 9, whereas Nos. 4, 10, and 11 are mixtures of coke and charcoal iron.

This fact is worthy of notice, when it is borne in mind that No. 11 gave the highest figures in all the tensile tests, and in no case fell under 28 kg. per mm. (17.78 tons per sq. in.)—that is, more than double the strength of common grey cast iron, for which a breaking-load of 12.5 kgs. per mm. (7.94 tons per sq. in.) is usually reckoned.

The great variety of results which were obtained by the 461 trials with all the 44 iron alloys, were also of high practical interest. All were so good that, when they were cast in chill, they radiated faultlessly, which will be perfectly clear to an experienced founder after what has been said above. Nevertheless, as far as strength is concerned, they showed the greatest variations.

The worst alloy, No. 1, bore exactly 38·5 per cent., or, according to the Charlottenburg tests, 32·8 per cent. of the best alloy, No. 11 ; and from this fact it can be gathered that a chilled cast iron section only shows whether the constituent parts of the pig iron were present in the right proportions, but does not show whether chilled cast iron also answers all ordinary demands regarding strength.

This fact is confirmation of what was stated at the commencement of this paper, namely, that the words "chilled cast" will never convey a fixed idea, and that it will never be applied to any specific iron alloy. Every chill foundry must, therefore, have the right of determining for itself what is intended to be understood by the term "chilled cast iron."

It is useless fixing certain rules for the chemical composition of a chilled cast iron alloy, and even the adoption of certain definite brands of iron as a basis is of no use ; for, as mentioned above, the trial bars from one and the same brand of iron can give very different results for each cross-section, according to the conditions under which they are cast and the dimensions which they receive.

Chemical analysis can, therefore, only supplement the strength-testing machine, but cannot replace it. Both are, however, of little value without the necessary practical experience of the founder, by the help of which he knows how to bear in mind and utilise the circumstances connected with the casting as a guide for the required data of the strength of castings from the brands in question.

If this practical experience is, however, at command, analysis and the testing-machine then become expedients which may nearly quite prevent uncertainties in the manufacture of chilled cast iron, and allow scientific methods to take the place of crude empiricism.

After Gruson had brought his material to such a high degree of efficiency, he did his utmost to secure for it suitable employment. With what certainty he proceeded, and what unbounded confidence he placed in chilled cast iron, can be best gathered from the circumstance that at the commencement of 1860 he proposed the use of chilled iron for shells. As was to be expected, his proposal was laughed at by the authorities, seeing that the idea of attacking wrought iron and steel plates with cast iron projectiles was con-

sidered absurd. Nevertheless Gruson's confidence was destined to find a brilliant justification. After the chilled shell had, in the year 1864, during the German-Danish war, proved itself to be a good attacking projectile against the Danish man-of-war *Rolf Krake*, it proved, during the course of numerous trials which took place from 1868 to 1874 on the firing-ground at Tegel, its superiority over the then still unhardened steel shell, alike in hardness, penetrating power, and cheapness. In England chilled shells, known under the name of "Palliser shells," are still largely manufactured. During the course of the last year, and since steel shells could be hardened successfully, chilled projectiles have certainly lost their former reputation. On no account, however, will they be completely supplanted, as they are now still employed successfully for various purposes.

For Gruson the success of his shells had still further important consequences. His material having exceeded all expectations for attacking purposes, he conceived the idea of using them also for protective purposes. The relations which, by means of his deliveries of shells, he had formed with the various Governments, were now of use to him, and chilled cast iron proved itself in numerous trials to be an excellent material for fortifications. It is especially the manufacture of chilled cast iron armour which has given the name of Gruson a world-wide reputation, and one which is still continually increasing.

The cupolas of the shielded mountings (system Gruson-Schumann) intended for inland fortification are now made of wrought iron or steel; the glacis armour, however, is still made of chilled iron. The manufacture of chilled armour for inland fortification has of late considerably increased.

For coast defences chilled iron has always been the sole suitable material.

Here the hardness and weight of the armour are of importance; the former prevents the projectiles from penetrating far into the armour, so that the strain on the substructure of the armour-plate is not too large. The great weight of the chilled armour-plates, however, serve to equalise this strain. For coast armour, chilled iron has been and is, therefore, in comparison with other materials, the best metal. It may be that technical conditions to-day allow

plates of sufficient thickness and weight to be made in other materials; these could, however, in no way compete with chilled iron in price, and will always be inferior to it in hardness.

Chilled cast iron armour for coast defences was submitted to its greatest trial at Spezzia in 1886. A plate, consisting of the 15th part of a cupola, withstood four rounds of the 43 cm. (16·9 inch) gun. The projectiles were Krupp's hardened steel shells, weighing 1000 kg. (about 2205 lbs. each), the charge was 375 kg. (826 lbs.) of brown prismatic powder, and the energy 14,700 metre tons (47,500 foot-tons) per shot. The plate was damaged and somewhat cracked on its exterior surface, but was not breached, and could have resisted further shots.

Chilled cast iron showed an equally great, if not as rapid, a development for industrial purposes. Gruson was the first to introduce in Germany, before 1860, "frogs" and crossings made of chilled iron for railway purposes. Such parts of rails, which come out of the mould very exact in shape, require only a little retouching, and combine, in consequence of the good material and the method of casting employed, a great hardness on their working surfaces, with great strength, so that they soon came into favour with all railway engineers at home and abroad. Chilled wheels were soon extensively used for railway purposes. They had, however, although they gave every satisfaction, to give way to wheels provided with steel tyres, which can be turned down in case they should lose their round shape. On the other hand, they have largely controlled the market for local railways, tramways in mines, and other industrial purposes. The large dimensions assumed by the manufacture of chilled wheels is proved by the fact that the Grusonwerk has over 600 different models and about 4000 chills of this description.

Besides "frogs" and crossings, switches made of chilled iron have found extensive use for tramways, worked both by horses and by steam; they have even become wholly indispensable for that use. The reason of this can be explained by the fact that the rails of tramways are subjected to dust and dirt, as well as affected by the wheels of carriages, so that their wear and tear is greater than that of railways.

The hardness of the above parts is, therefore, of great importance in the case of tramways, which explains the fact that for such pur-

poses chilled cast iron is nearly solely employed. At the commencement it was very difficult to cast the long narrow points, having a length of $3\frac{1}{2}$ metres, in chills, as they easily lost their shape. After Gruson had, however, surmounted these difficulties, chilled iron met with great success for tramway purposes, and it may with confidence be expected that they will also maintain their position here, as well as in mine and field railways, for the future.

Considering the great number of rail profiles, it was necessary to make a corresponding number of models and chills. For instance, the catalogue of the "Grusonwerk" relative to tramway material for the year 1888 is a large work of 320 pages, and contains sketches of 428 models, which number has been increased by 200 since the catalogue was published.

The mixtures of chilled iron are subject to different modifications, according to the mode of their employment; whereas for railway purposes the crossings, having a small depth of hardness, are employed; the machine industry necessitates considerably greater depths of hardness.

Machines intended to work hard materials must especially possess a great depth of hardness on the exterior surface. Of such machines the rolls are in the first place of importance. Chilled iron appears to be especially suitable for rolls, as their surface is already hard when they come out of the chill, and their tough interior prevents them from breaking.

The manufacture of chilled iron rolls is very old, and, as was mentioned before, had to remain within certain bounds, as chilled metal did not possess strength enough for great strains. Further, the demand for hard rolls was only small as long as this industry was little developed.

The chief difficulty which had formerly troubled most engineers, and caused them to abandon the matter, viz., the finding of a right mixture of sufficient hardness, could certainly be considered solved, after experience enough had been gained, on account of the more extensive production of chilled iron from German pig iron. Another not less important difficulty arose in the extraordinary hardness of the material, which could not be worked with ordinary tools.

The manufacture was, therefore, restricted at the commencement

to such rolls as needed no working, such, for instance, as unworked pressing rollers, smooth and fluted rollers, and roller-rings for ore, clay, quartz, emery, and chamotte mills.

The manufacture really only commenced to flourish when it became possible to turn, grind, and polish chilled rolls.

Only a special kind of the hardest tool-steel can be used, as the rolls themselves are as hard as common tool-steel. This steel having been produced, there were no more difficulties in the way of turning the rolls; only strong turning lathes. An exact roundness is only given to the rollers on the grinding lathes, where they are made to rotate slowly, and are worked with emery discs. The latter make about 3000 revolutions per minute, and are slowly moved up and down the rollers, whereby they are in constant contact with them.

The rolls leave the lathes completely round, and show a polished surface, which is increased on the polishing lathe. The polishing can be effected in various ways, the most useful being perhaps the use of leather discs.

The use of chilled rolls for working raw materials is considerable, and may be referred to in a few words.

The calibre rolls for the manufacture of shaped iron and steel, and the smooth, polished rolls for the manufacture of iron, steel, copper, brass, zinc, nickel, gold, silver, tin, &c., are specially important.

Whereas the rolls for the manufacture of metals make the greatest demands on the experience of the founder, rolls for the paper, cardboard, and rubber industries demand the greatest accuracy and care on the part of the grinder.

These rolls are usually, in comparison to their diameter, very long, and bend through somewhat in the centre, as soon as the tenons are under pressure. The rollers must, therefore, not be exactly cylindrical, as the paper would then be thicker in the middle than at the sides. The rolls are, according to the pressure they have to sustain, made in such a way that their diameter in the centre is larger than at the two ends. If the rolls are then brought upon each other under a certain pressure, they lie together tightly. The grinding of a long paper roll necessitates, as can be gathered from the above, the continued earnest attention of

the grinder, as the smallest mistake at any one place will cause the whole roll to be re-ground. How careful the grinder must be can be seen from the fact that rubber tissue, for instance, which is used by doctors, has sometimes to have a thickness of only $\frac{1}{30}$ th mm. The polishing must also be done faultlessly, for the smallest mistake will be seen on the pressed paper. The smallest pore on the surface renders the roller useless, and even differences in the hardness of the roller have a bad effect during the grinding and polishing, so that the manufacture of good rollers for the paper and rubber industries can be looked upon as something of a masterpiece.

One of the chief modes of employment of chilled iron has long been for crushing purposes. Here the working parts are often subjected to the highest possible strains, as the materials to be crushed, such as stones and ores, are often of the hardest nature, and soon destroy machines made of inferior material.

The most important machine for preliminary crushing is the stone-breaker, which is to-day made in the most varied constructions.

Similar to this are the breaker-jaws, which are merely plates provided with wide grooves, and arranged in such a manner that they can easily be placed in a machine and taken out again. Here, also, considering the purpose in view, a large variety of constructions has been necessary; the "Grusonwerk" alone having over 600 models and chills for breaker-jaws.

For the further treatment of hard stones, ores, and earths, roller-mills are employed.

The chilled rollers for such mills are always used in an unfinished state—that is, the exterior surfaces are now worked.

The use of rollers for corn-grinding, an industry which has developed rapidly within the last twelve years, also deserves mention. The greater the progress made in the manufacture of rolls, the more they have been used for milling purposes. Such rollers are mostly provided with fine grooves. They are cast hollow, turned down, and then pressed on steel axles. These axles then run in bearings, and the rollers are first ground and then they are brought on to special fluting machines, where the grooves, running in a screw line, are cut in. The edges of these grooves must be pretty

sharp; they dare not break, however, and, on the other hand, they must be so hard that they do not prematurely become blunt. The manufacture of these rolls necessitates, therefore, much experience, and especially so because they must possess a great depth of hardness without prejudicing their toughness, so that by frequent grinding the soft layer does not appear. They must also have a thoroughly even hardness, or they will otherwise wear unevenly.

Many thousands of such rollers were furnished by the "Grusonwerk" to England eight to twelve years ago, before English factories were in a position to make such rolls.

In order to be able to form an idea of the extent to which rollers are used, it may be of interest to know that the "Grusonwerk" has more than 1500 models and chills for their production.

Another machine for crushing ores, stones, cement, earth, &c., is the edge-runner, whose chilled cast-iron rings usually have a diameter of 650 to 1500 mm., and a width of 160 to 400 mm. The substance of the plates on which the runners run, and which, in order to be easily exchangeable, consist of segments, is chilled iron. The largest and heaviest runners are used in the manufacture of powder. They are massive, cast in chill, and have a weight of about five tons.

Chilled iron is further used for screw-mills, whose crushing apparatus is the so-called breaking-screw, which is of chilled iron, with screw-threads about five cm. deep, and turns in an iron case. The floor of the latter consists of a row of chilled bars, through whose fissures the material crushed by the screw falls. Screw-mills are especially used for grinding soft minerals, such as soda, sulphates, &c., but they also serve in place of roller-mills for grinding hard substances, such as limestone and cement. The dies and shoes of stamping batteries are also made of chilled iron.

In the case of cone-mills, where the grinding takes place by means of a fluted cone, which turns round in an inner fluted mantle, both are made of chilled iron cast in grooved chills. Cone-mills which are employed for pulverising soft materials, such as salts, sulphates, coals, boiled bones, wood, &c., are remarkable for their large output.

Finally, a machine must be mentioned whose working parts likewise consist of chilled iron, and which, within the last few years, has found extensive employment. This is the ball-mill, which serves for grinding basic slag, cement, ores, &c., without making any dust, and which is constructed specially solid and durable.

Besides these machines serving for crushing and disintegrating, chilled cast iron is much used for other special machines, which would either be subjected to too great wear if they were made of softer material—such as guides and guide-blocks for railways, lifting cans, friction rollers, ploughshares for sewing-machines, fingers for mowing-machines, &c.—or which necessitate great hardness combined with strength, such as pressure dies for the manufacture of briquettes, slag-stone forms, piston-heads, hammers, boring and driving hammers, anvils, swages, punching plates, paving-beetle plates, picks, cylinders for road-rollers, &c.

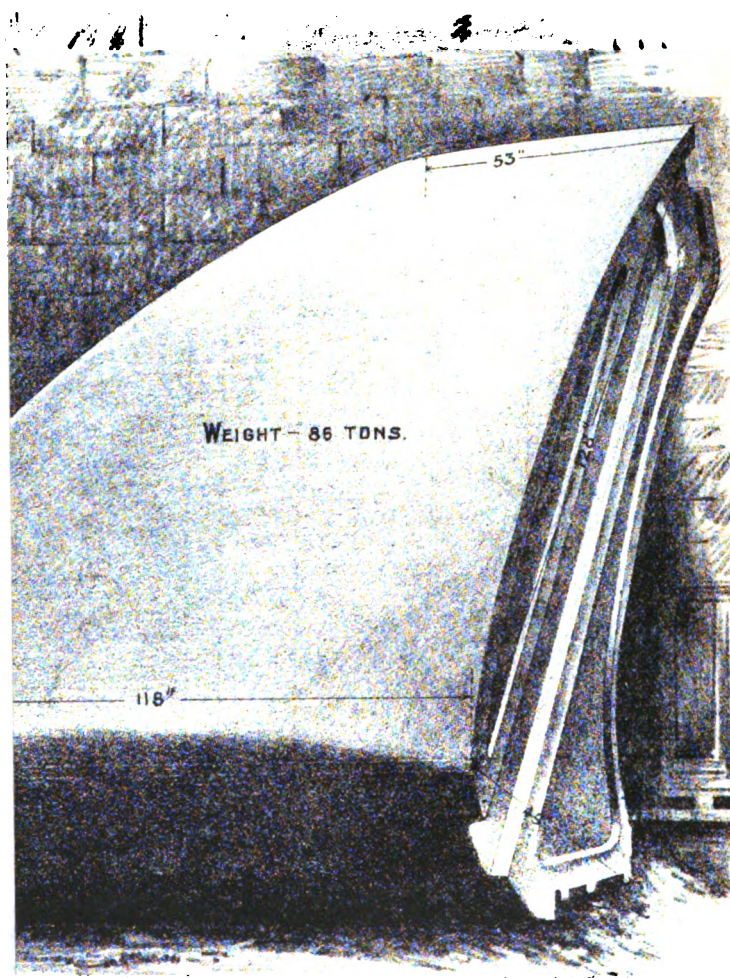
After the brilliant results of the trials of strength of chilled iron, which proved it to be twice as strong as common cast iron, its use, when cast in sand or loam moulds, was extended to many parts of machinery which are subject to great strains, such as steam-cylinders, hydraulic presses, steam pistons, small turntables and transfer plates, toothed discs for coal and coke breakers, brake-blocks, alarm guns, as well as signal and railway platform bells. Another property of chilled iron makes it useful for certain purposes. On account of its consistent grain it is not only fire-proof, but also withstands the influence of various chemicals, so that it is specially suitable for pans and retorts in chemical works, melting boilers for lead and zinc, soda and sulphate pans, annealing pots for file-makers, boilers for boiling salts and acids, fire-bars, &c. &c.

The grinding discs of the Excelsior mills, a grinding and grist machine built by the "Grusonwerk," of which over 12,000 have been sold since 1880, are worthy of special mention. This rapid increase of the sale of this machine is solely due to the grinding discs of chilled material, whose small, sharp teeth could not be made strong and exact enough in any other material. If Gruson metal has now been replaced in the case of many of these machines by steel, the perfection of which has been successfully achieved, the former

will never lose its value for industrial purposes, and the demand for it has always been on the increase.

Although the "Grusonwerk" has for about five years had its own steel-works, which are fitted up in the most modern style, and whose productions are not excelled by any others, chilled iron still forms the chief manufacture, the works having taken up as specialities all machines in the manufacture of which chilled iron is employed.

HILLED IRON CASTINGS.



Hilled Cast-Iron Armour Plate in Gruson Turret.



DISCUSSION.

Mr. E. REIMERS said he had brought over with him some broken specimens of cast iron which were exhibited on the table. To give an idea of the dimensions of such chilled cast-iron armour plates as were mentioned in the paper, he had caused a diagram to be prepared, showing the front view of a plate as supplied to the Italian Government at Spezzia. The dimensions of the plate were, at the bottom 4 feet 1 inch, and at the top 2 feet 6 inches. The backing had a thickness of from 18 to 20 inches. The weight was 90 tons. The breadth at the top was 4 feet 5 inches, and at the bottom 9 feet 10 inches. The total weight of such armour made for Spezzia was 1375 tons, and of glacis armour about 925 tons.

The PRESIDENT invited discussion on the very interesting account, which Mr. Reimers had given, of the successful achievements of Mr. Gruson in the attainment of uniformity in the production of chilled iron of various degrees of hardness, combining the requisite toughness and tenacity, as well as in the many important applications of the material, of which, perhaps, one of the most remarkable was the application of chilled iron to defensive purposes.

Mr. CHARLES WOOD said he thought that every one who had seen the samples must have been very pleased and much instructed by them. One great defect, or rather omission, in the paper (for which they were all very much obliged) was that there were no chemical analyses. The chemical analysis, in the selection of pig iron for making chilled castings, was the thing that they required, and was the very essence of the whole question of chilling. Some few years ago he read a paper at the Glasgow meeting of the Institute,* in which he pointed out the extraordinary effect that silicon had on pig iron. It was a well-known fact that Cleveland pig iron, or iron containing a large percentage of silicon, would not chill in the least. They might make very fine thin castings on the chill and yet not have any effect in the shape of chilling. That depended entirely upon the quality of the silicon.

* Vol. No. ii. 1885, p. 464.

If the silicon were reduced to about one-half or three-quarters of 1 per cent., the same iron would chill very well. Therefore, it would be seen what an essential thing it was to get the analysis of the different qualities of iron, and to know what brand of iron to select.

He thought Mr. Reimers had made a slight mistake in saying that the crossings or frogs were first introduced by him. When he (Mr. Wood) was serving his apprenticeship at Ransome's, of Ipswich, a patent was taken out and worked for many years by Mr. Allan Ransome and by Mr. George Biddell, and they were applied to nearly all the railways in the kingdom, and even in the present day they might be occasionally seen lying on the railway. Those were all chilled, and chilled equally fine and even deeper than the specimens on the table. These chilled crossings had been in common use all these years, and were introduced in the early part of the "fifties." Those were replaced later on by the cast steel crossings, which had rather more durability, and were lighter and not quite so liable to break, and later on were made out of steel rails. Chilled castings generally had been in use for forty to fifty years.

Another example which he thought they all knew was the chilling in connection with agricultural engineering. Going back to that date, again, there were the railway chairs made by the Ransomes of Ipswich, and known as Ransome's patent chilled cast chairs, of which he had made a great many hundred tons in India from charcoal iron, in 1855 and the following years. The irons chiefly employed at Ipswich, he believed, were partly Wear-dale and partly Welsh irons, the depth of their chill depending entirely upon the quality of the iron. At that time the question of silicon was not thought of, nor was chemical analysis resorted to; and, therefore, the knowledge of what irons would chill was very limited indeed; in fact, there were very few such irons in the market. All agricultural engineers knew that chilled plough-shares had been made for fifty to sixty years, and were, perhaps, the most beautiful specimens of chilled castings to be seen. They were not any thicker than a quarter of an inch, and the defined line of chill was very remarkable.

About the year 1853 there was a very large telescope or transit

instrument for the Cape of Good Hope made for Sir George Biddell Airey, the Astronomer Royal, the bearings of which were all chilled, and turned up with specially hardened tools. The chills on the axles were worked up to $\frac{1}{36,000}$ part of an inch. He had sat for weeks watching the spirit levels. They were very beautiful specimens of chilling, and the journals were about 7 to 8 inches in diameter, and were chilled from about a quarter of an inch deep. They were so excessively hard that it was a long time before they could find tools to touch them. From the tone of the paper, and seeing those specimens, it might be thought that chilling was not understood in this country, and had only been carried out in Germany. He therefore hoped that he would be excused for making these remarks. As he had said before, the paper would have been very much more complete had Mr. Gruson been good enough to give a chemical analysis of the different qualities of iron employed, so that they could know what qualities of iron to choose from when they required to make chilled castings.

Sir BERNHARD SAMUELSON, Bart., M.P., said he hoped that the author was prepared to give some further information with reference to the process employed by Mr. Gruson. When a paper was brought before the Institute, it was always expected that it should give such details as would be interesting to those concerned in the manufactures of which it treated. He was sure when the author wrote the paper he could not have been aware of the conditions observed by those who submitted papers; but he had no doubt that all the information which would be of interest to the members was fully in Mr. Reimers' possession, and he hoped, when the discussion on the paper closed, that they should have such details from him as would make the paper and the discussion worthy of the Institute.

Mr. E. A. COWPER had been about to express the same idea, although, probably, in different words. Long before the date named in the paper, ploughshares, chilled rolls, chairs, and many other things, had been sold as a regular matter of business in England; these were thoroughly and efficiently chilled to any depth required. Messrs. Ransome were particularly proud of

their ploughshares. The chilled rolls were obliged to be chilled very deep. There was a little dodge about casting chilled rolls which he might mention. The chills had to be made very thick, and warmed, and wiped round the inside with a composition or wash of a little stale beer and mealed gunpowder; and when they were perfectly dry, and the metal was poured in, as it rose the composition and air were burnt off the surface, and the roll was chilled deeply. If they did not do that, they sometimes got air between the metal and the chilled mould, which prevented proper chilling.

Sir JOHN G. N. ALLEYNE said if they were going into the antiquity of the subject, perhaps he might be allowed to say a few words. Perhaps everybody did not know what the word "tramway" came from. It came from "Outramways"—Mr. Outram being one of the original partners in the Butterley Works. He believed one of the earliest tramways was from Kilburn Colliery to Derby, and the crossings of that "Outramway" were made of chilled iron. He should be very proud to put it on the records of the Institute that "tramways" did really come from Outramways, and that they were certainly older than the author of the paper.

Mr. REUBEN FARLEY said he agreed with the observations which had fallen from previous speakers. He thought they had a very great deal of force in them, because the paper was not of a sufficiently practical character, and not likely to be so useful to those members of the Institute who were ironfounders as it certainly might have been. It was deficient in tables of analysis, which a paper like that ought certainly to contain. Although Mr. Reimers did not claim Mr. Gruson as the inventor of chilled cast iron, he did ignore the fact that chilled castings were largely made in England many years before Mr. Gruson was born. He had no hesitation in saying that in South Staffordshire, which was the home of the English iron trade, chilled rolls were not unknown at the end of the last century—chilled rolls for rolling sheet iron, for rolling boiler plates, for rolling hoop iron, and for rolling tinplates and various metals in the metal mills of Birmingham. As one of the previous speakers had said with regard to chilled ploughshares,

those were made very early in the present century by Messrs. Ransome of Ipswich. Chilled boxes were also made for the axles of cart-wheels and waggon-wheels in the early part of the present century, if not in the last century; so that chilled castings and chilled rolls were made in England long before they were ever made in Germany. England, which was, of course, the home of the iron trade, at one time and for many years produced nearly all the iron that was supplied in the markets of the world.

He had been rather struck with one observation contained in the paper—that the iron in the Gruson Works was melted in cupolas. So far as his experience went, he did not think it possible to bring out the best results by melting iron for chilled castings in cupolas. He believed it was far better to melt it in a reverberatory furnace—what is generally called or known as an air furnace. By melting the iron in an air furnace, they were able to arrange for trials and to test the metal. The skilled ironfounder knew when he had the sand trial and the chilled trial whether the iron would produce the depth of chill which he required. Of course, the depth of chill required for cold rolling was very different from the depth of chill required for hot rolling. So it was that the ironfounder had to vary his mixtures to suit varied requirements. It was the art of his business to know how to modify and regulate his mixtures to produce the results required by his customers. For casting chilled rolls the pig iron which was produced from the argillaceous ores of Shropshire and South Staffordshire was remarkably well adapted; and if these ores were smelted in a small blast furnace, say of only about 100 tons per week—not of large capacity—and if pure coke, as free as possible from sulphur, was used, and the ores were carefully selected and of good quality, he was of opinion that iron could be produced which would make as good rolls as it was possible to make from charcoal iron.

He did not wish to disparage charcoal iron for a moment, but having had long experience of casting chilled rolls, he had no hesitation in saying, as the result of his experience of iron from the Blaenavon Works, in South Wales, and some other works that he could mention, as well as from the cold blast furnaces of Shropshire and South Staffordshire, that they were remarkably well

adapted to produce satisfactory results, and were, in fact, essential for that end. A low silicon iron (cold blast or charcoal iron) containing about 1 per cent. of silicon, and an iron which was as free as possible from sulphur and phosphorus, was the best pig metal for producing good chilled castings. They required an iron of great tensile strength, and for rolls it was especially necessary that the castings should be as free as possible from pinholes and cracks. If the author of the paper had given some information as to how the ironfounder could cast rolls absolutely free from pinholes and cracks, and defects of that description, he would be conferring a lasting benefit upon some of the members of the Institute. He hoped that if the author fell in with the suggestion which had been made as to revising his paper, he would give that information, of which at present it was deficient.

Mr. G. H. STRICK said that, being a manufacturer of iron for chilled castings, though not a manufacturer of chilled castings themselves, he should like to say a word or two on the subject. He was about to allude, as everybody else had alluded, to the absence of chemical analyses, but he should like, if they were going to be favoured with further information on that point, to be told what were the proportions of silicon and manganese, to which allusion was made in the paper, which were considered the most advantageous for iron of that description. Mr. Farley had alluded to the influence of silicon, but he should like to draw attention to the influence of manganese, which he thought, within certain limits, had an influence of importance.

Mr. Farley had also alluded to the difficulties that occurred from cracks and pin holes. It had come to his notice more than once that iron containing exactly the right proportion of silicon, sulphur, and phosphorus had given unsatisfactory results in casting chilled rolls, and difficulties had occurred from cracks in the chilling. That question had been referred to him on one occasion, and he had endeavoured to elucidate it in some measure. He found that the proportion of manganese happened to be considerably less than in the standard pig iron. The proportion of manganese in that particular instance was only 0.3 per cent. By the addition of manganese to about 0.7 or 0.8, which he thought

was the proportion generally found in iron made from the argillaceous ironstone of Staffordshire and South Wales, that difficulty was overcome. He had also noticed in the iron manufacture that when they had a pig containing exactly the same elements with the exception of manganese, when manganese happened to be low—about .3 per cent (which was low for that class of iron)—they had a pig which set very rapidly in the ordinary sand mould, but they could see the face of it chilling at once, as it were, and also the action of the occluded gas playing about underneath. When they broke the pig, he had often noticed blowholes to the extent of perhaps one-tenth of the whole section. But by the addition of a little manganese, either in the shape of manganiferous ore, or, perhaps, with greater certainty and not greater cost, by the addition of a little spiegel, raising the manganese up to what he should call the normal point, .7 or .8, they got an iron which did not set so rapidly in the moulds. They could see the face of the pig playing about; a much more satisfactory iron was obtained, which broke stronger in the pig, and the difficulty in the chilled casting resulting from cracks pretty well disappeared.

He should be glad of information showing what was the standard proportion of silicon and manganese. He thought it was understood that the sulphur should be as low as possible, and that the phosphorus should not exceed the limits of .3 or .4; but he thought the proportions of silicon and manganese, influencing as they did the chilling of iron, was a matter of importance, and he should be very glad to have further information upon that point.

MR. CHAS. A. WINDER, M.Inst.M.E., said, as a manufacturer of chilled iron articles, particularly chilled rolls, he had many points brought before him with regard to its difficulties. There was one matter which Mr. Reimers had not fully gone into, although he had alluded to it, viz., the hardness of the chill. The author spoke about the hardness being the same as in common tool steel. That was rather erroneous, because if chilled rolls were only as hard as "common tool steel," they would be of no use whatever. The users wanted something especially hard to be of any service. There was no standard gauge by which it could be estimated except by actual use, or possibly the careful use of the file would

form a comparative test; but he had found that the best test of the hardness was that of a well-tempered centre punch. For some purposes a mild face was wanted—that was, a perfectly white chill, with the lines radiating from the surface, and a grey background, a chill in which they might bury the point of a centre punch; and for other purposes a very hard chill was required, and by using the same centre punch it would smash up, and have very little effect upon the chill. Those were points which the author had not alluded to. To assume that the chilling iron gave a constant result in all cases was very misleading. He thought if the author were to send down to Sheffield rolls only as hard as steel, he would find something there that would very soon take the face off them. The people in Sheffield would not have anything except that which turned a good blue colour on the plates and bars. He had found that the rolls that had not a hard surface were useless for that purpose, and they would not have them at all.

He wished to ask another question. How was it that England was sending rolls to the Continent—into Germany, France, and Belgium—in such enormous quantities? He was not going to speak of his own firm, but would take the roll trade generally. Taking the chilled iron trade and the roll trade together, he did not know the figures, but he should consider, from what he knew, it must run into a very large amount, for he had been told that when the Continental people had once used the English rolls they would not use any other. The reason, he understood, was simply because they were much harder on the face, and turned a better colour, as well as wore much longer.

The author appeared to make no distinction in the nature of the chilled face, but if they made a chilled roll for rolling steel or iron out of the same metal which was used for paper work and calendering purposes, it would simply be of no use at all. And, on the other hand, if they made a chilled roll for calendering purposes from the same iron which was used for steel and iron, it would be very soon returned on their hands on account of the different nature of the chill required. They wanted a distinctly different sort of chill for calendering purposes from that wanted for rolling steel, &c., and this applied to all branches of the chilled iron trade. The

depth of the chill did not determine the hardness, for a chill half-an-inch deep might be harder in one class of iron than a chill of $1\frac{1}{2}$ inches of another sort. In other words, taking a roll with a chill half-an-inch deep, and making another casting of the same class of iron with more carbon in it to make it an inch and a half deep, they might both be of equal hardness, as the carbon in chilled iron had a very different effect than when it is used in steel-making; for the addition of carbon did not harden the face, but simply made the chill all the deeper. The hardness of the face was due to other causes, many of which were beyond the present knowledge of chemistry, and which he had not been able yet to establish. He knew how to attain it by certain means; but there were certain matters in metallurgy, particularly in the matter of cast iron, which were very little understood. Although he had been for twenty years working at the subject, both practically and chemically, he was only beginning to find how much there really was to learn. He considered that the gases had a great deal to do with it. He did not assert it as a fact, as he had not proved it, but there was something behind that was very mysterious. If the author could help them in that direction he would earn the thanks of the members.

Mr. JAMES ROBERTS said he thought the members must be obliged to Mr. Reimers for the interesting specimens he had put on the table, and to a certain extent for the paper which he had brought before them. He said to a certain extent, because if the author had not brought the paper before them there would not have been any discussion upon the question of chilled cast iron. At the same time, he felt that they were suffering under the great disadvantage of having certain facts stated without the means being stated by which those facts were arrived at. He would first of all take up the question of the tests, of which the author had given a list in the paper. It would have been of very great interest to the members, and would probably have elucidated the reasons for the variations in the text, if the author had appended a chemical analysis of the whole of those tests. They would then have been able probably to judge of the causes of the variations. There was one matter in connection with those tests which to his mind was

rather astonishing, and that was that Mr. Gruson got on a bar three feet long and one inch square (and they must bear in mind that it was a German inch and not an English inch, which made a difference of $\cdot 7$ of a square millimetre in favour of the German inch), with the test applied to the centre of the bar, a breaking strain of 30 tons, whereas on the same bar, turned down to an area of one square inch, he only got a tensile strain of 16 tons 8 cwt. That was contrary to all practice, and to all his experience. He should have said that a bar which would bear a tensile strain of 16 tons 8 cwt. would not have stood on an inch bar in 3-feet bearings, with the weight applied in the middle, more than 12 or 13 cwt., instead of which the author said he had had 30 tons.

He thought the author owed them some explanation of how he arrived at the 30 tons transverse strain applied in the middle of a bar simply an inch square. The author had given those tests as something remarkable. Certainly the transverse strains were very remarkable, but the tensile strains were not remarkable at all. He should say that for charcoal iron they were rather low; in fact, he had got better strains than the author had given, on an English square inch, from ordinary cold blast iron of the South Staffordshire and Shropshire districts. He had made some tests a short time before, and had got 17.9 tons from a Staffordshire bar an inch square, which was less in area than the square inch which Mr. Reimers gave. With regard to deflection, in the transverse strain, with the weight on an inch bar of $13\frac{1}{4}$ cwt., which was equal to 53 cwt. on a 2-inch by 1-inch bar, he got a deflection of $\cdot 725$.

In the analysis which Mr. Reimers had put upon the board [Mr. Reimers wrote some analyses on the black board while the discussion was in progress], he stated the total carbon, but the carbon which affected the chilled rolls was the relative proportion of combined carbon with graphitic carbon, and he should be very much obliged if the author would put that upon the board, and show them to a certain extent how the combined carbon varied from the graphitic carbon, because that was the crucial point with regard to the hardness of the chill obtained. With regard to the phosphorus, it was a moderate amount, probably lower than was

got in their cold blast pigs; his silica was about the same, and his sulphur was not remarkably low; but his manganese was much higher than those who practised in England used. He thought that the author would find, if he used iron with that amount of manganese, that the hot metal rollers would be sending the rolls back as fast as they could get them in between their housings.

He thought that Mr. Reimers, in the first part of his paper, had taken a great deal to himself in stating that all the development of chilled cast iron was due to the fact that it had been made from German pig iron. He knew as a fact that the firm he represented made chilled rolls in 1812, many years before Mr. Gruson was born, and that they had been successful, and were making those rolls up to the present day. He could not admit that it was due to the superior quality of the German pig that he had been enabled to make all those wonderful things which were shown. He spoke and felt as an Englishman, and he emphatically said that they in England had done all those things which Mr. Gruson had brought before them. If the author had given them more analyses, they would probably have been able to meet him with other analyses. Mr. Gruson had stated that his combined carbon should be under 1 per cent. Of course, there were circumstances in which the combined carbon should never exceed $\cdot 5$, and there were circumstances in which they could get less than $\cdot 5$, and yet obtain a perfectly sharp and clear chill, and the rolls would work better. There were other circumstances in which they must have over 1 per cent., 1.2, or even 1.3 in their rolls, if they were to get perfectly satisfactory results from them. He did not think, therefore, that there was a great deal to learn in that direction, but they might learn more from the mixtures if the author had given the analyses of the various test bars.

The PRESIDENT said that Mr. Reimers was very anxious to give some explanation through him of what appeared to be a great defect in his paper. He desired to explain that, while he had been asked by the Secretary to prepare a paper, he had received no indications of the character of paper required, but that he was quite ready now to add the analytical information which, it had been pointed out, was needed to render a proper comparison of the

different mechanical test results possible. Mr. Reimers had requested him also to say that, while he thought he had been a little hardly treated by gentlemen who did not know all the circumstances under which he had been asked to prepare the paper, he would be pleased to have it returned to him for the insertion of such analytical information as he could supply. The President was afraid Mr. Reimers was not sufficiently a master of the English language to reply to the various questions that had been put, but he thought the members ought, in fairness, to allow Mr. Reimers to see in print the remarks that had been made, and he would then, no doubt, send such a reply as he would otherwise have given at that moment.

He might point out, in reference to the question of the development of chilled castings in England, about which their German friends did not appear to be quite so well informed as Englishmen were, that, unfortunately, no one was present from the Arsenal at Woolwich, who might have informed Mr. Reimers that the question of the manufacture of chilled projectiles was worked out contemporaneously with Mr. Gruson's work, and quite independently, by Major—afterwards Sir William—Palliser, who had established a reputation as a thoroughly practical man, a man combining great skill in experiment with very considerable scientific knowledge.

Mr. Reimers had stated that the chilled shells were first used in 1864 during the German-Danish war; and he referred to experiments made from 1868 to 1874 on the firing-ground at Tegel with chilled projectiles prepared by Mr. Gruson. The Palliser shot were first fired at Shoeburyness in November 1863, and from that time experiments had been systematically made in the shell factory at Woolwich. And our knowledge of the composition of the material necessary for the production of chilled shot of excellent quality was, as early as 1870, so fully developed that since that time little or no improvement had been effected in the production of chilled projectiles. Before this they were entirely cast in chill, but from that period only the head was chilled; the gradual transition from a dead hard head to a base which was really soft iron, being obtained by a combination of chilled casting and sand casting. The members would, he knew, allow him to return thanks to Mr. Reimers for the great trouble he had

taken, and to assure him that no discourtesy whatever was intended towards him in the somewhat sharp criticisms which had been made on his paper. Members quite understood that it had been a misunderstanding as to what was required which had led to the furnishing of only imperfect information in the paper before them.

Mr. REIMERS, in replying on the discussion, through the Secretary, says: So far from finding fault with the paper presented as not being sufficiently full, English founders ought really to be very grateful to me, as I have shown them by the data and figures given how and in what direction they may extend and increase the manufacture of their chilled cast iron, and that chilled cast iron may be used for an endless number of other articles besides rolls. For indeed the roll-makers have only spoken of the paper from their one-sided point of view, and have hardly touched upon the use of this iron for other articles, for they seem to have no interest in such. I have spoken in my paper of chilled cast iron generally, as it is manufactured in Grusonwerk, and had not the intention to speak of its manufacture in England specially, as I must naturally leave that to those gentlemen interested in it. I had quite as little intention to choose specially the manufacture of rolls from innumerable other articles of manufacture, and to speak on that point only, as was evidently not only desired, but even expected, by several gentlemen. I grant that I might have mentioned the chilled iron of England as I did that of America, but I did not do so, inasmuch as English chilled iron is never spoken of in books on that subject, but one hears always of American chilled wheels and paper rolls. If my paper contained nothing new to some members, I have at least the certainty that it gives some information to those members who are not engaged in the manufacture of chilled iron, and who must be the majority.

To Mr. Wood I reply, that had I known the value he and other speakers set on analysis, I would very gladly have given them some. I think, however, I have shown him, by the data given as to the strength of chilled iron, what the Grusonwerk is capable of executing in that way. I may mention—although it is stated in the paper—that very great value is placed on strength, as well as on

analysis, in our works. By analysis one can always secure a high degree of hardness, but not always at the same time a high degree of strength. The Grusonwerk, however, considers great strength of more importance. If it is possible to attain a high degree of strength, it is not very difficult to obtain the necessary hardness. There is no reason to reproach me because I was ignorant of the fact that crossings were made of chilled iron in England in the "fifties," but as Mr Wood has informed us of the fact, there is nothing more to be said on that point. In any case, English chilled iron articles were not used or known in Germany at that time, and it was indisputably Mr. Gruson who first made these articles from German materials in Germany, and introduced them into the trade there with success. It is really not a question of who first made this or that article, but rather who has learnt to manufacture this article in such a way that its quality answers to all the far-reaching demands of the present time. As to ploughshares, I will not enter into this subject, and as to what Mr. Wood tells us about the axles and bearings of a telescope, I can only say that similarly exact work in chilled iron has often been carried out by the Grusonwerk. I shall speak about the desired analysis later on.

To Mr. Farley I reply that it is repeatedly stated in the paper that both the use and the manufacture of chilled iron, as also of chilled iron rolls, were known some time before Mr. Gruson commenced to employ this material for other purposes.

With regard to the employment of reverberatory furnaces, I am fully aware that an excellent quality of chilled iron can be obtained with them, but good quality is attainable by many methods, and it must therefore be left to the manufacturer to employ such melting apparatus as appears to him most suitable for his method of manufacture and the purpose in view.

This is not the place to examine whether the reverberatory furnace or the cupola furnace is to be preferred for English foundries. I have stated the fact that the Grusonwerk employs cupola furnaces entirely, and for this reason, that these are most suitable for their special method of manufacture. In any case, all chilled iron articles cannot be cast with advantage from reverberatory furnaces—as, for instance, those ploughshares, about which

so much has been said, were certainly not cast from reverberatory furnaces. This must be quite evident to a technical man, as he knows quite well that he can easily cast eighteen or twenty different chilled iron articles exactly according to a pattern, one after another, in a corresponding length of time from a cupola furnace. I hardly think Mr. Farley is able to do this with his reverberatory furnace at all, but certainly it could not be done in the same time.

The cupola furnaces in the Grusonwerk are of ordinary construction, with cylindrical shafts; they have from four to nine blast pipes of 4 to 8 inches diameter, and these smelt the iron with a 12 to 24 inch water pressure in corresponding proportions of white and grey, employing the best and cleanest coke. Before the casting is undertaken samples are taken out and cast in chills, in order to test the depth of the chill, and if necessary the iron is regulated accordingly. Of all large castings, in which great strength is important, testing rods of from 1 to 4 square inches thick, according to the necessary depth of the chill, are taken daily, and on the next day they are broken on hydraulic breaking machines, weighted in the middle with a length of 1 metre, free. The necessary thickness of these test-rods depends upon the desired depth of chill of the metal. The deeper the chill is to be, the thicker must be the rods; for strength and depth of chill are exactly proportional to the thickness of the rod. The temperature of the iron, in which the latter must be cast, is an essential factor in the success of a chilled casting. The temperature must be regulated according to the size of the casting, and this can only be done properly by the experience of the founder. The founder must know the properties of the materials to be used in the casting most accurately, and whether his metal contains a great deal of silicon or of manganese, in order to be able to produce a good casting. According to the experience of the Grusonwerk, the casting should always take place from the lowest point of the piece cast—for instance, with rolls the iron should be conducted into the chill so that it rises tangentially. The chills should in most cases be warmed before making the cast. Chills made out of the best pig iron, containing plenty of silicon and little manganese and phosphorus, must be regulated in size according to the purpose

for which they are used, but for this purpose one cannot give fixed rules. The dimensions must be determined for each single case according to experience.

While one is able to give no definite formulæ and rules for this, it is just as impossible to give fixed analytical formulæ for hardness, and still more impossible is it to give definite mixing formulæ or receipts for the different depths of the chill. This is all due to the many unavoidable circumstances attending the production of the pig iron, such as the burning out and changing of the furnace-shaft, and wet or dry ore or combustibles, on the quality of which these have a material effect. Even the size of the cupola furnaces has an influence on the quality of the chilled iron—that is to say, whether the furnace is wide or narrow, and whether the smelting takes place quickly with a high pressure, or slowly with a low pressure, influences the hardness and the depth of the chill. It is, in fact, the business of the smelter, and of the manager of the foundry, in each case to regulate everything according to their experience, and to satisfy themselves by tests of the chill, and afterwards by breaking tests, of the good quality of the material. Every founder of chilled iron knows that with chilled castings one gets more or less cracks from the heat, or even a porous casting; but these difficulties can be overcome by different methods learnt by experience, and can in any case be reduced to a minimum; and, where repeatedly occurring from the same cause, can be entirely obviated. These cracks generally show themselves in castings of a very great hardness and depth of chill, as also when the chills are separated in many parts, where seams or projecting pieces hinder the contraction. The cracks or pinholes resulting from the hardness or heat of the chill can be avoided by having the casting warmer or colder, by larger or smaller charges, at proper places, by a proportional temperature of the chill, by having parts of the chill movable, by a suitable varnishing of the surface of the chill, by making the chill as far as possible in one piece, and by many other artifices more or less trifling in themselves.

Mr. Winder is quite right in saying that the degree of hardness is an important factor in chilled iron articles, quite apart from the depth of the chill, and that an instrument would be most valuable, with which one could examine the degree of hard-

ness. The Grusonwerk have always felt the need of being able to satisfy themselves of the degree of hardness, and have endeavoured to construct an instrument suitable for this purpose, having originally used the primitive method of the centre punch and hammer mentioned by Mr. Farley. In later times, however, they have employed an apparatus provided with a diamond, which can be used by means of adjustable lever weights. The diamond is first brought over the piece, the hardness of which is to be tested, without being subjected to any weight, so that it leaves no trace or cut behind. If the diamond be then gradually weighted when loaded to a certain degree, which can be read off from a scale, it commences to cut, and produces a cut more or less deep, according to which the degree of hardness can be calculated. In addition to this so-called cutting apparatus, there is also a falling apparatus, by means of which a cylindrical rod or die, with an obtuse-angled hardened point, falls from a fixed height on a polished piece of chilled iron, and according to the size of the impression which this machine makes after one or more falls on the piece of iron, the hardness is estimated. Mr. Winder wishes me to give him the best methods for testing the hardness, and I am sorry not to be able to inform him whether the methods I have given are the best, or whether there exist still better ones; but anyhow, better methods are not known to me, and as far as I know the different degrees of hardness could not be discerned with certainty by chemical analysis.

Mr. Roberts holds the opinion that if certain facts are stated, the means by which these facts are attained should also be given. I must contest with him the right to demand this, even for a paper read before the Iron and Steel Institute. It must be quite sufficient for him, when I tell him that the Grusonwerk is able to accomplish this, and it must remain at my discretion whether I find it desirable to communicate the means or not.

Probably Mr. Roberts would not have lost so many words about the figures of the strength of flexure given by me, if he had reflected that the figures, which seemed to him so surprising, are to be understood to show the strength of the outer fibre; and that these figures indicating the strength should by no means be multiplied as a unit with the contents of the area, in order to obtain the load which

would break the middle of the rod, for the strain on the various fibres of the cross section of the bar when being bent is not at all uniform, a fact which is well known.

I have given in the table below some analyses of the different articles made in the Grusonwerk. To these analyses are added at the same time the depth of the chill obtained by the iron mixture given, and the weight to which the rods were subjected for the transverse strain, as well as the observed flexibility :—

Analyses of Chilled Castings produced at the Grusonwerk.

Carbon.	Combined Carbon.	Graphitic.	Phosphorus.	Silicon.	Sulphur.	Manganese.	Depth of Chill in Mm.	Breaking Load per sq. Mm. in Kg.	Deflection before Breaking in Mm.
3·535	0·410	3·125	0·410	1·440	0·077	0·648	5	36·4	25
3·547	0·402	3·145	0·508	1·446	0·080	0·820	10	47	26
3·497	0·603	2·894	0·482	1·365	0·082	1·278	20	54	28
2·837	0·351	2·486	0·670	1·070	0·193	0·590	20	46	18
2·896	0·493	2·403	0·592	0·812	0·235	0·446	25	45	16
3·889	0·782	3·107	0·279	0·859	0·091	1·355	35	37·6	14·5
3·625	0·780	2·845	0·387	0·606	0·086	0·995	40	43·3	14
3·540	0·545	2·995	0·351	0·513	0·074	0·936	40	42·2	14·5
3·295	0·590	2·705	0·399	0·793	0·055	1·253	45	47·1	15·5
3·490	0·670	2·820	0·335	0·835	0·047	1·469	50	48·9	16
3·755	0·815	2·940	0·247	0·728	0·083	1·928	50	39	9

I may remark again that the depth of the chill is proportionate to the thickness and strength of the rod, on account of which fact the thickness of the rod to be broken is always chosen according to the depth of the chill. I will mention here, in addition, for the sake of making myself clear, that a rod of 1 square inch in thickness, cast from a chilled iron mixture, which yields a depth of chill of from 40 to 50 millimetres, would bear almost nothing. The rods for such a mixture must have a thickness of from 2 to 3 square inches. This has already been mentioned in my paper, but I think it necessary to state the fact again.

It would have been better if Mr. Roberts had refrained from criticism on rolls with what he considered too high a percentage of manganese, for it was not stated for what purpose these rolls were employed. In the Grusonwerk rolls are manufactured with a very low percentage of manganese, or with a very high one,

according to the purpose for which they are intended, as, for instance, whether they are for edge-runners or for metal rolls. Mr. Roberts and some of the other speakers spoke frequently of rolls, but I have had no reason, as I have already stated, to confine myself to rolls, for I prepared my paper, not to deal with the manufacture of rolls alone, but with the manufacture of castings generally. Otherwise, I should have had to treat many other articles in the same minute manner, and this was not the object of the paper. I would, moreover, especially draw Mr Roberts' attention to the fact that I speak in my paper, as the title itself plainly says, of the manufacture of chilled iron according to Gruson's system. The great honour which I am said to have attributed to Mr. Gruson, Mr. Roberts can in no way take from him, as Gruson alone has employed chilled iron for a multitude of purposes, from the smallest article to the heaviest armour-plate.

ON PLATINUM PYROMETERS.

BY H. L. CALLENDAR, M.A., FELLOW OF TRINITY COLLEGE, CAMBRIDGE.

MANY different kinds of pyrometers have been from time to time proposed, and have come more or less into use, for purposes of practical measurement. The great majority of these leave very much to be desired in point of efficiency and accuracy. I propose to confine my remarks mainly to two special kinds, the air pyrometer and the electrical resistance pyrometer, between which, I believe, the ultimate solution of the problem will be found to rest.

The great interest and importance of the air thermometer lies in the fact that it is the ultimate standard to which measurements of temperature must be referred. The laws regulating the expansion of gases are well known and understood, so that by measuring the increase of pressure or volume of a certain quantity of air enclosed in a suitable bulb of glass or porcelain, it is possible to calculate its temperature approximately on the true or absolute scale.

The theory of the air thermometer is extremely simple and perfect, but the practical difficulties in the way of constructing and using it are very considerable. This difficulty is well illustrated by a comparison of the results obtained by different observers. The boiling-point of zinc, for instance, the temperature of which is only moderately high, has been determined with the air thermometer, with results varying between 1080° and 900° C., a discrepancy of nearly 200° between the extreme values. If we take only the best and most careful experiments, the discordance is still considerable. Probably the most careful and accurate measurements yet made are those of Deville and Troost in 1880.¹ Using the same air thermometer in the same apparatus, under similar conditions, and employing the greatest precautions to secure accuracy, they obtained values varying between 954° and 929° C., a difference of 25° between the extremes.

¹ *Comptes Rendus*, xc. p. 773.

The fundamental difficulty in the use of the air thermometer is the difficulty of procuring a material for the bulb which shall be rigid and air-tight at high temperatures. If, for instance, the bulb is made of platinum, the most infusible and unalterable metal that can be readily obtained in sufficient quantities, it is found to occlude or absorb a certain quantity of the air, which inevitably vitiates the results; and, further, it is shown to be very porous to several common furnace gases at a temperature of 1000° C. Deville and Troost employed bulbs made of the hardest porcelain, glazed both inside and outside with felspar. This is a much more satisfactory material than platinum, but after a time the glaze inevitably cracks, and the air contained in the pores of the porcelain introduces an incalculable factor into the observations.

I have made many experiments myself with air pyrometers, both of platinum and porcelain, and have reluctantly come to the conclusion that really satisfactory results cannot be obtained with either of these materials. There is another material, however, with which I have experimented, of which I have greater hopes. The material I refer to is pure silica. It is an exceedingly refractory material, but at a sufficiently high temperature it fuses into a viscid liquid, which can be worked and blown like ordinary glass. It has, in addition to its infusibility, physical properties of toughness and hardness and elasticity, which make it in every way superior to glass or porcelain for scientific purposes. Unfortunately, owing to the high temperature at which it softens, it is very difficult to work, and requires considerable skill. I have only as yet succeeded in making very small tubes of this material. With further practice and larger apparatus I hope, however, to be able ultimately to make tubes and bulbs of dimensions suitable for air thermometer work. The material possesses all the requisite qualities, and I have no doubt that with its aid it will be possible to make really satisfactory instruments.

There is another difficulty in the way of the practical use of air pyrometers. The theory is delightfully simple. The pressure or the volume of the air in the bulb, whichever you prefer to measure, is simply proportional to the temperature measured on the absolute scale. But in actually measuring the pressure or

the volume, there are several practical difficulties in the way of securing accuracy. (1.) The air in the bulb must communicate with the measuring apparatus by means of a tube containing air. The expansion and contraction of this air in the connecting-tubes must be estimated and allowed for. (2.) The barometric pressure and the temperature of the surrounding air are constantly changing. These both enter as factors into the calculations, and have to be noted at each observation.

The result is that the calculations become somewhat formidable if any reasonable degree of accuracy is desired. For laboratory work this is not a serious objection, but it would be quite intolerable to the practical man. What he wants is an instrument which will indicate the temperature *directly* and *continuously*, without the trouble of calculation or constant adjustment.

Take, for instance, Wiborgh's air pyrometer, which has recently been described in the *Journal of the Iron and Steel Institute*, 1888, No II. p. 110, and 1891, No. II. p. 130, and is one of the neatest and most reliable of commercial pyrometers. At 1000°C . the correction to be applied for the temperature of the surrounding air amounts to about 90° when the attached thermometer reads 20°C .; and a change of 1 inch in the height of the barometer involves a correction of about 50°C . These corrections cannot be neglected, and their application involves a certain amount of trouble and additional observation. Moreover, the instrument does not read *continuously*. At each observation of temperature it is necessary to force the mercury up to a certain level by means of a screw adjustment. In this instrument no account is taken of the air in the connecting-tubes, which is necessarily a further source of error.

The maker has recently introduced an exceedingly pretty and ingenious *aneroid* modification. The corrections, as before, have to be made by special adjustment, and the instrument does not read continuously. The aneroid form is undoubtedly more handy than the other; but, having regard to the well-known defects of the aneroid barometer and the imperfect elasticity of materials, I should not like to place much reliance on the constancy of volume of an elastic metallic box which was periodically squashed flat; and should feel very much disposed to doubt the maker's unqualified assurance that it is "perfectly accurate" in its indications.

I have recently succeeded in devising a comparatively simple form of air pyrometer, which does all its own corrections automatically, and indicates the temperature continuously on an ordinary scale. This instrument is a modified and compensated form of the familiar differential air thermometer. A description of it has been published in the *Proceedings of the Royal Society* for December 1891. It is compensated in such a way that its readings are not affected by changes in the temperature of the surrounding air, or by variations in the temperature of the connecting-tubes. It is also completely sealed up, so that it is independent of the atmospheric pressure. With bulbs of hard glass it is possible to read up to 700° C., and the performance is all that could be desired at these temperatures. I have tried the instruments at higher temperatures with bulbs of platinum and porcelain, but, for the reasons previously given, their performance is then not so satisfactory. A bulb of fused silica would probably answer the purpose. Such a bulb, however, has still to be made.

To sum up, the great advantage of the air pyrometer is that it is possible to calculate the temperature approximately on the absolute scale. For theoretical work this is extremely important, and that is why I have devoted so much space to its consideration. For practical purposes, however, it is by no means essential, and the air pyrometer has several disadvantages. It is difficult for several reasons to make it read with sufficient delicacy and accuracy at high temperatures. It is necessarily fragile, unwieldy, and difficult to manipulate. There is always the trouble of making air-tight joints, and of finding a material for the bulb which remains sufficiently rigid and impervious at high temperatures.

The second form of pyrometer to which I referred, namely, the electrical resistance pyrometer, is, in my opinion, much better suited for practical work. It is much more sensitive and constant than the air thermometer, and also much easier to read and manipulate.

The action of the electrical resistance pyrometer depends on the measurement of the change of electrical resistance of a wire. Electrical resistance thermometers are generally made of platinum wire, owing to its infusibility and freedom from liability to chemical change. For this reason they are often called

simply "platinum pyrometers," which is the name by which I shall generally refer to them in what follows.

Matthiessen showed many years ago that the resistance of a wire of almost any pure metal increased nearly in proportion to the absolute temperature. The resistance of a pure platinum wire increases by about 34 per cent. between 0° and 100° C. At 1000° C. its resistance is about four times as great as at 0° C. Not only is the increase of resistance very large, but it can be very accurately measured. The measurement of resistance is much the most simple and exact of all electrical measurements, and there can be no doubt that thermometers constructed on this principle can be made much more sensitive and accurate than any other kind. They have a great advantage in this respect over thermo-couples. The electromotive force of a thermo-couple is by nature very small, and could not in any case be measured with the same ease and accuracy as a resistance.

The merit of having worked out the platinum pyrometer in a practical form, and of having introduced it into general use, undoubtedly belongs to Sir W. Siemens. In his Bakerian lecture in 1871 * he explained the theory of the method, and described instruments capable of indicating temperatures up to 1000° C.

The great convenience and advantage of the method was at once realised, and a committee of the British Association was appointed to test the instruments, and report upon them. Their report, however, which was published in 1874, disclosed a most serious practical defect. The committee experimented chiefly with a pyrometer in an ordinary fire at moderate temperatures of about 800° C., and they found that the resistance of the pyrometer increased continuously with continued heating, and that the wire underwent rapid deterioration. They also made some experiments and suggestions with a view to remedy this defect, but they did not succeed in overcoming it. This continuous change of zero is certainly the most serious practical defect that a pyrometer can have, and there can be no doubt that the report of the British Association did a great deal to destroy confidence in this method of measuring temperature.

About seven years ago, when I began making experiments on this subject at the Cavendish Laboratory, Cambridge, I was at

* See also *Transactions of the Society of Telegraph Engineers*, 1875.

first very much surprised to find that the platinum wires which I used did *not* undergo continuous change, even when subjected to much more severe tests than those applied to the Siemens pyrometer by the committee of the British Association. By making further experiments, however, with a sort of imitation Siemens pyrometer, I succeeded in reproducing at pleasure the effects they had observed, and in proving to my own satisfaction that these defects were not inherent in the method, but merely incidental to the particular form of instrument on which they experimented. I found that if the wire was properly protected from strain and from contamination,* the pyrometers could be made practically free from change of zero, even at very high temperatures. Now, since I claim to have succeeded in constructing pyrometers on this principle which are free from this defect, I feel that it is incumbent on me, in order to restore confidence in the method, to explain the particular defects of construction of the Siemens pyrometer to which its changes of zero are due, and to show how they may be avoided.

The construction of the Siemens pyrometer has not, so far as I am aware, undergone any material change since 1874. The coil of platinum wire, which forms the sensitive part of the instrument, is wound on a clay cylinder, and packed in an iron tube from five to eight feet long, and about an inch or so in diameter. I have here the fine wire and the clay cylinder from a pyrometer which was recently in use at the Royal Arsenal, Woolwich. I was informed that it had never been heated above 900°C. , or 1600°F. , but its resistance had increased some 15 per cent., corresponding to an error of about 100°F. in the temperature measurements. When the instrument was taken to pieces, it was found that the wire was quite rotten and brittle in some places and sticking to the clay cylinder. This, I think, is sufficient evidence that the clay, or some impurity contained in it, attacks the wire, otherwise the local nature of the action could not be explained, unless the quality of the wire used was very inferior.

I have tried several materials on which to wind the wire, but have found nothing that answers so well as mica. The plan I generally adopt is to double the wire on itself and wind it round a very thin plate of mica, in such a way that it only touches the

* *Phil. Trans. R. S.*, 1887, pp. 161-230.

mica at the edges. This method gives very good insulation, even at high temperatures, and, so far as I can discover, the mica has no action on the wire even at temperatures of 1200° C.

Another defect of the Siemens pyrometer is the iron containing tube. Metallic vapours of any kind will attack the wire readily, and will ruin the pyrometer. It is not probable that the iron itself will be appreciably volatile at temperatures below 1000° C., but it is very likely to contain several more volatile impurities. Vapours of copper, tin, zinc, &c., rapidly render the wire brittle and useless. A comparatively small trace suffices. Here, for instance, is a pyrometer with copper electrodes, which has been kept at a temperature of about 850° C. for an hour or so in a porcelain tube. The discolouration of the mica in the neighbourhood of the copper leads shows that the copper was appreciably volatile at this temperature, 150° C. below its melting-point. The resistance of the platinum coil was in this case increased by nearly $\frac{1}{2}$ per cent., owing to the action of the copper. For this reason copper or silver leads cannot be used in pyrometers for high temperature work.

The pyrometer which I have handed round has silver leads, and is intended for working up to temperatures of 700° or 750° C. only. It is enclosed in a tube of very hard glass, which does not begin to soften till nearly 800° C., that is to say, at a bright red heat.

For work at high temperatures it is essential to use leads of platinum, which must be fused, not soldered, on to the fine wire of the coil. Solder of any kind is quite inadmissible, and screw contacts, such as are used in the Siemens pyrometers, are clumsy and liable to change their resistance with repeated heating.

Glass cannot, of course, be used for the containing tube in high temperature work. In my experience a hard-glazed porcelain tube does very well to protect the wire, at least up to temperatures of 1200° C. A silica tube would probably do even better, but I have not yet succeeded in constructing such tubes the requisite size.

The instruments which I have here are enclosed in porcelain tubes. Their interior construction is precisely similar to that of the pyrometer which I have handed round, except that they have platinum leads. This particular pattern is intended for laboratory

work, and for testing small samples; but you will understand that they can readily be made of any other pattern to suit furnace-work. For some kinds of rough work it is convenient to protect the porcelain or glass tube with an outer tube of iron, and to make the instrument much larger.

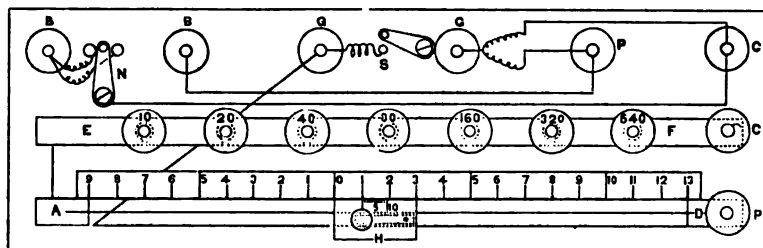
It has been objected that the necessity of enclosing these pyrometers in a porcelain tube is a serious drawback, on account of the size, expense, and fragility of the tubes. I would first observe that, whatever kind of pyrometer is used, it is necessary to protect the sensitive portion in some way, if results of any accuracy are desired. Even with a thermo-couple the wires must be insulated, and must be protected from contamination, or it is necessary to cut off the junction and graduate the instrument afresh. Secondly, I would observe that porcelain has hitherto been found to be the most suitable material for high temperature work, and that good porcelain tubes are not so fragile as is commonly supposed. I have only as yet had the misfortune to break one tube, and that was with a hammer. The pyrometer in question had been in use for about six months. The exterior of the tube had been attacked by lead-oxide, alumina, cast iron, and other powerful reagents, and had been very roughly treated in scraping off adherent masses of metal and slag. At the close of some experiments at the Mint with Professor Roberts-Austen the pyrometer suddenly refused to indicate. We supposed that some metal must have found its way through the tube, and a *post-mortem* examination was accordingly performed with a hammer. To my great annoyance I found that there was nothing the matter with either the tube or the pyrometer, and that the defect was simply due to a short circuit of the external leading wires, caused by the softening of the gutta-percha insulation. Since then I have taken the precaution of insulating the leading wires with silk or asbestos, and have not had the misfortune to break any more tubes.

So far I have described only the construction of the pyrometer itself. The construction of the indicating portion of the apparatus, and the method of measuring the resistance, is a question of almost equal importance.

The resistance of one of these pyrometers can, of course, be measured by any of the usual methods, but the sensitiveness and

accuracy attainable depend very largely on the selection of a suitable method and apparatus. In the case of the Siemens pyrometer, the differential galvanometer method has been adopted. A resistance-box is used reading to $\frac{1}{100}$ th of an ohm, which corresponds to about 3° Fahr., and a table is issued giving the resistance for every 20° Fahr. The disadvantages of this method are (1) that the readings are discontinuous, (2) that it is necessary to refer to the table, and do an interpolation sum to find the temperature.

The differential galvanometer method is, moreover, for other reasons, unsuitable for accurate work. It is essential to use the Wheatstone bridge method. For use with my own pyrometers I have adopted the most accurate modification of the latter method, in which a bridge wire is used for reading the fractions. The advantages of this method are (1) its superior accuracy; (2) that the readings are continuous; (3) that the divisions of the wire may be made to correspond directly to degrees of temperature. The principle of the method has already been described and explained in a paper published in the *Philosophical Magazine* for July 1891. The following is a diagram and description of a form of resistance-box specially made for the purpose:—



Resistance Box and Bridge.

The pyrometer leads marked P and C are connected to the terminals marked P and C. The battery is connected to the terminals marked B, and the galvanometer to the terminals marked G. AD is the divided wire with a millimetre scale and vernier H, reading to a hundredth of a degree. EF is an adjustable set of resistance coils. The numbers on the heads of the screw-nuts E to F give the equivalent values of the corresponding resistances in centimetres of the bridge wire. The resistance

coils themselves are compensated, so that changes of temperature of the box do not affect their values.

In taking an observation, resistances are unscrewed or unplugged in the arm EF, and the galvanometer contact piece H is moved along the wire till the balance is found. The reading of the bridge wire, added to the sum of the coils unscrewed, gives the value of the temperature directly in degrees on the platinum scale.

With this apparatus 1 centimetre of the divided wire corresponds to 1° C. It is not difficult to make the galvanometer sensitive to one-hundredth of a degree at 1000° C., and, of course, one-tenth of a degree, which corresponds to one millimetre of the bridge wire, can be read with tolerable ease and certainty.

With these instruments it is not only possible to read with certainty to a tenth of a degree at 1000° C., but what is more surprising and important, the readings are actually constant and consistent to this fraction of a degree. I have made several experiments to test this point. Some typical illustrations will be found in a series of experiments made at the Royal Mint in conjunction with Professor Roberts-Austen, and described in the *Philosophical Magazine* for February 1892. In the present state of our knowledge I do not think it would be possible to construct a pyrometer on any other principle, to read with anything approaching to this degree of accuracy. There are very few instruments that can be made to read even to 10° with certainty at 1000° C., and the possible errors of most pyrometers are much larger than this.

It may be objected that so high a degree of accuracy is not required for most practical purposes. It is, however, undoubtedly valuable for scientific work, and, of course, there is no difficulty in constructing less delicate instruments in cases where the highest degree of accuracy is not required.

For the most accurate work the bridge wire or "null" method possesses undoubted advantages. For practical purposes, however, it is in many cases more convenient to use a "deflection" method. In the Wheatstone bridge method, and also in the differential galvanometer method, the resistance is measured by balancing it against another resistance, which is adjusted by trial until the balance is obtained. This necessity of continuous

adjustment is particularly troublesome in cases in which the temperature is *varying*, and in which, for this very reason, a high degree of accuracy is out of the question.

A platinum pyrometer can, however, be easily arranged so that the odd degrees of fractions are directly indicated by the deflection of the galvanometer, instead of being found by sliding the contact piece along the bridge wire till the deflection is nothing. If, however, the ordinary form of galvanometer be used, its deflection will depend on the strength of the battery as well as on the change of resistance. It is, therefore, necessary either to use a constant battery, or to compensate the galvanometer so that its deflections are independent of the battery power. The second plan is, in my opinion, the best. Constant batteries are very liable to get out of order, and are never quite constant. It is better to use an ordinary electric bell or telephone battery, and to compensate the galvanometer.

The deflections of an ordinary galvanometer will also vary with the resistance and temperature of its coils. The galvanometer must, therefore, also be compensated for change of temperature of the air, so that it may give the same readings in summer and winter. Since, after all, the galvanometer deflection is only used for giving the odd twenty or thirty degrees and not the whole temperature, this might be regarded as a superfluous precaution; but it can easily be shown that this is not the case if you wish to read *with certainty* to a tenth of a degree.

I have recently succeeded in compensating a galvanometer in a comparatively simple way, so as to satisfy both conditions. The deflection of the galvanometer is then proportional to the change of resistance of the pyrometer, and is independent both of the strength of the battery and of the temperature of its coils. With a mirror galvanometer, compensated in this way, it is possible to read to a tenth of a degree with tolerable certainty at 1000° C. My own instrument gives an angular deflection of twenty-five minutes for 1° C., with a possible error of less than five minutes in a deflection of 15° of arc.

Most people who are not practical electricians find a mirror galvanometer rather difficult and troublesome to work with. For ordinary purposes a needle galvanometer is sufficiently accurate, and certainly much easier to read. The annexed diagram re-

presents the arrangement of the apparatus for working with a needle galvanometer at any temperatures up to 1500°C .

AA' represents the pyrometer in its containing tube connected by the flexible leads LL, which may be of any convenient length to the terminals PP, CC of the indicator. A common Leclanché or dry-battery is connected to the terminals BB. By means of suitable switches, not shown in the diagram, any number of different pyrometers in different places may be alternately switched on to the same indicator. The needle N of the galvanometer is furnished with a long fine index, which moves over a scale divided into 100 parts. R is a resistance-box, preferably of dial form, and mounted on the same base as the galvanometer. The travelling plug T can be inserted in any one of the holes so as to vary the resistance in the circuit. The resistance of the pyrometer is adjusted so that a change of 1 ohm corresponds to 100°C . or Fahr., whichever may be preferred. The remaining coils and resistances forming the Wheatstone bridge are contained in the galvanometer case. The connections, &c., are not shown in the diagram, to avoid unnecessary complication.

In taking an observation, the temperature is generally known beforehand to within 100° . The plug T is inserted in the corresponding hole. The key K is then depressed, and the needle of the galvanometer at once indicates the odd degrees and fractions. In the position shown in the diagram the temperature indicated is 930° . When the needle falls below 0 the plug T must be shifted backwards. When it rises above 100 the plug is shifted the other way. An arrangement is also provided for keeping the key K permanently depressed when the temperature is to be indicated continuously.

The use of this form of instrument requires no special electrical knowledge or skill. The observations are such as any intelligent workman can readily make. It is many times more sensitive than any of the ordinary forms of pyrometers, its readings are also much more constant and trustworthy, and there are no calculations to be made or corrections to be applied.

For many kinds of rough work, and particularly for work in furnaces and blast pipes, it is not necessary to read with this degree of accuracy throughout the whole scale. In many cases the temperature is only required roughly, say to 5° or 10° . For

this purpose the auxiliary resistance-box R may be dispensed with, and the whole temperature indicated by the deflection of the galvanometer. This, of course, makes the apparatus much simpler and cheaper, as the resistances are expensive and difficult to adjust. By suitably adjusting the scale of the galvanometer it can be made to cover any desired range, such as 0° to 1000° C. or Fahr., instead of 0° to 100° .

In cases where greater accuracy is desired, but only *over a small range*, such as 1000° C. to 1300° C., the resistance-box may also be dispensed with, the pyrometer and the galvanometer scale being adjusted so as to start reading at the desired point. One great advantage of these pyrometers lies, in fact, in the ease with which they can be adapted to suit any particular kind of work.

Another advantage of these pyrometers, which I pointed out some years ago,* is that different instruments, when properly adjusted, agree in their indications very closely indeed throughout the whole scale. In the case of pyrometers constructed of the same wire the largest difference I have hitherto observed is only half a degree at 1000° C., and even in this case I cannot be quite certain, because the pyrometer which showed the divergence was not quite so well made as the others. With pyrometers constructed of different specimens of wire the divergences are still very small, even if the electrical coefficients of the wires differ by as much as 10 or 15 per cent. In any case such small differences are readily dealt with, in cases where a high degree of accuracy is required, by reducing the indications by means of a table of corrections to those of a standard instrument.

For practical purposes it is comparatively little use to endeavour at present to reduce the indications to the scale of the air thermometer, because the latter instrument cannot at present be made to read with certainty even to 10° or 20° at 1000° C. To the practical man it does not very much matter whether the scale of his instrument be Centigrade or Fahrenheit, or absolute or arbitrary. What he wants is an instrument which will always give the same indication at the same temperature, so that, having once discovered the temperature necessary or most suitable for any particular process, he can make certain of reproducing the

* *Phil. Trans. R. S.*, 1887, p. 162.

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TINUM

same conditions at will at any future time. This desirable result can, I believe, be most perfectly attained, as far as our present state of knowledge goes, by the use of platinum pyrometers. Since different platinum pyrometers can be made to agree very closely in their indications, the results obtained by different observers will then be fairly comparable if expressed on the platinum scale. If the greatest accuracy is desirable the readings can be still further reduced to the scale of some particular standard pyrometer. In this way we shall at least be able to secure uniformity in place of the bewildering discrepancies at present existing. The platinum pyrometer will preserve the standard, and if at any future time it becomes possible to make more accurate measurements with the air pyrometer, all the observations previously made will not be simply wasted, as they are under the existing want of system, but can at once be expressed in terms of the new standard.

DISCUSSION.

Mr. CALLENDAR said that for lack of opportunity he had not yet been able to make experiments actually on iron and steel, which, he believed, were the experiments most interesting to the Institute. He was only about to introduce some different kinds of pyrometers which, he was told, would be very useful for the purpose of investigating the qualities of iron and steel, and which, he believed, could be so applied, because he had tested them practically up to the temperatures required.

Sir LOWTHIAN BELL, Bart., F.R.S., said he quite agreed with what had fallen from the author with regard to the Siemens electric pyrometer. His firm was amongst the first to make a trial with it, but they had experienced the inconvenience which had been spoken of, and that which could not be too sufficiently enlarged upon, viz., its complication and liability to go wrong. After being at work for a certain time, its indications ceased to be trustworthy. When he heard of the pyrometer which had been brought under their notice by their colleague, Professor Roberts-Austen, he at once ordered one, and had made a good many preliminary experiments. He was so satisfied with the pyrometer that he had placed one in a small building connected with the office. From this, wires were laid to all the furnaces, so as to ascertain the temperatures of the escaping gases and of the blast, which really were the two points in a blast furnace that they were most immediately concerned with. Unfortunately, the Durham strike, among other inconveniences, had prevented their testing the efficiency of the plans they had adopted, but he had no reason to suppose that there would be any difficulty in their being able, by the help of a laboratory attendant, to take the temperatures of all the furnaces, some of which were situated at distances of from 200 to 300 yards from the point of observation. One could not look upon those attempts to make a perfectly accurate pyrometer with anything but satisfaction, because the proper way to proceed in those matters was to investigate, and to make one's self master of the laws upon which they depended. They were quite willing,

however, when the time came, to make some sacrifice of perfect accuracy to durability.

He saw that on the first page of his very interesting paper, the author spoke of a discrepancy of 25° Cent. as being objectionable, and in pure science this was perfectly true, but in furnace work they could afford to overlook 25° , which did not represent more than 15 lbs. of coke or thereabout on the ton of iron, and was near enough for practical purposes. He could only say that he wished every success to the author in his endeavour to obtain a perfect pyrometer. With regard to the silica bulbs, he should like to know what size those bulbs were required to be?

MR. CALLENDAR said that bulbs such as that on the glass thermometer on the table would do quite well.

SIR LOWTHIAN BELL said that silica was not a very manageable substance to work with, so far as fusion was concerned, and he would therefore suggest rock crystal or quartz as a possible material for the thermometer bulbs, which must be formed by drilling the cavity in the solid material, and in that way they would have a bulb without the necessity of fusion.

MR. CALLENDAR said the difficulty in that case would be that they would have to connect the bulb in an air-tight manner to a long tube, and the tube itself must be of silica also, and could not be satisfactorily joined to the bulb, unless they could melt it on. But if bulbs could be bored of the requisite thinness and uniformity, that would be a very good way undoubtedly.

MR. E. A. COWPER said he thought the observations of Sir Lowthian Bell were very interesting and important, because it seemed to him that he had put into their heads a means of finding out what was going on in the furnace on the two important matters he had mentioned, the gases and the blast. It was a very pretty arrangement of the use of electricity.

Professor BARRETT said he had listened with deep interest to Mr. Callendar's paper, and he thought the members were all very much

indebted to him for the remarkable improvements he had made in the Siemens pyrometer. He had not the least doubt that that instrument would enable them to make additional experiments on the critical points in iron and steel, confirming the temperatures that had been arrived at. He was going to ask Mr. Callendar to what degree of sensitiveness the instrument would read at a temperature of 1000° Centigrade? He should like to know how far it could be trusted and what error there might be, and in what way he removed the difficulty of the resistance of the leads?

Mr. CHARLES WOOD said he had had a great deal of experience and trouble with pyrometers. He had brought out one himself some years ago, in which one column was of porcelain and the other was of metal, and several kinds of tin, through which the hot blast current travelled; but with that, and with metallic pyrometers for intense heats, and also even with the Hobson's pyrometer, he found the hot air acting upon a metal, and varying the results through unequal expansion and molecular change. In employing a Siemens pyrometer, where a ball was dropped into the water, with constant use the metals underwent the same change, and unless, as in the case of the Siemens pyrometer, the ball was constantly renewed, and an uniform weight of ball kept to, the results were more or less unsatisfactory. All pyrometers in which the metal came in contact with the heat underwent a molecular change; the metal was altered in specific gravity, and he looked upon the electrical pyrometer in the same light—that is, if the platinum wires were constantly subjected to a very high temperature they would undergo the same change, and the resistance would be greater; and, therefore, the current passing through would, as the metal got more or less altered, show a different result from what it did in the first instance. He was rather afraid, therefore, that that would take place in the electrical pyrometer. He did not think, at present, they had arrived at what might be called a good practical pyrometer that could be carried about the works in the hands of the workmen. If any substance, other than metallic, could be obtained, with a definite distance through which they could get a current to pass, they might arrive at that point, but, at the present time, he was afraid that that result had not been accomplished.

Mr. CALLENDAR, in reply, said a question had been asked with regard to the degree of accuracy of the pyrometer at 1000° Centigrade. Using a mirror galvanometer like the delicate instrument described, it was not at all difficult to make it *sensitive* to the 100th part of a degree at that temperature; in other words, the change of 100th part of a degree would affect the galvanometer. It was not possible, however, to read *with accuracy and certainty* to more than $\frac{1}{10}$ th of a degree. He had tested the degree of accuracy, chiefly at the melting point of gold and silver, on different occasions. He had taken observations at the melting point of silver in his own rooms, and at the Royal Mint, and he had found with two different specimens of pure silver, and making the observations with the same instrument, that the different observations agreed to $\frac{1}{10}$ th of a degree.

The question was also asked as to how he got over the difficulty of the resistance of the leading wires? That, of course, had to be compensated for. The method in which that compensation was effected had been fully described in a previous paper published in the *Philosophical Magazine*. He had, therefore, said nothing about it. It was simply done by means of a dummy pair of leads, which would be seen in the instrument he had handed round for inspection. It would be observed that there were four leads, two going to the pyrometer, the other pair being simply a dummy pair, whose object was to eliminate automatically the change of resistance in the leads of the pyrometer itself. In that way the change of the resistance of the leads was accurately compensated for. Of course, the great difficulty with regard to any new pyrometer was that people always doubted whether it would not undergo a continuous change of zero with continuous heating. It would be seen in the paper that he had tested that point to a very much higher degree of accuracy than was ordinarily required in commercial work. Even at temperatures of 1200° Centigrade, the pyrometers, if properly constructed, did not change their zero by $\frac{1}{10}$ th of a degree. He had not heated pyrometers for many years; he had only heated them for, perhaps, two or three days; but if in two or three days they did not show a change of zero of $\frac{1}{10}$ th of a degree, he thought it pretty safe to conclude that they would not show any very large continuous changes of zero. The change of zero

in the Siemens pyrometer depended, as far as he could ascertain, first, upon the clay on which the wire was wound—it attacked the wire and altered it chemically—secondly, on the metallic vapours in the tube, due to the fact that it was enclosed in an iron containing tube. He thought that he had got over both of those difficulties by adopting the method of construction which had been fully explained in the paper.

The PRESIDENT said he was sure that the members were much indebted to Mr. Callendar for the care with which he had brought the subject before them, and he congratulated him upon the success which had been achieved by the very careful and systematic way in which he had eliminated the errors due to the construction of the original platinum pyrometer, upon which there seemed to be little reason to doubt that he had made a very great advance. The President trusted that the improved pyrometer would soon receive that amount of practical application which would give them all confidence in the trustworthiness of its results, even after it had been for a considerable time in use.

NOTES ON FUEL AND ITS EFFICIENCY.

PART I.

THE CALORIMETRIC ESTIMATION OF FUEL.

PART II.

NOTES ON A NEW OPTICAL PYROMETER.

BY B. H. THWAITE.

No stimulus to improvement in any industrial process is so great as that produced by severe competition, which means extinction of one of the rivals by the awful, if just and natural, law of the survival of the fittest. The value of labour, owing to restrictive legislation in the present, and still greater interference in the future, is more definite and less elastic year by year, so that to effect a reduction in the cost of production, recourse to the labour element for help is becoming a forlorn hope; the industrial *esprit de corps* is becoming more and more lamentably absent, and consequently the manufacturer is compelled to ascertain whether, in the processes of manufacture, some improvements may not be effected by which economy may be obtained.

It has become an established principle in many of the most progressive and modern manufacturing concerns, to maintain a staff of experts purely for investigation, research, and for experiment in imitation of the Industrial Chemical Laboratories of Germany, that have raised the chemical manufacturing industries of that country to the premier position in Europe. The absorption of this active principle of industrial and continuous experimental investigation by British chemical manufacturers is an accomplished fact,

and in the large new erection at Widnes, the controlling expert staff of the Alkali Union will eventually have, it is believed, an ample equipment to prosecute practical researches, the fruit of which cannot but be an advantage to the perfection of the industrial procedures, and as a logical sequence prove beneficial to the shareholders, whose material improvement will be an advantage to the nation.

Broadly, a metallurgic process may be thus divided into three parts :—

- 1st, The treatment of the raw materials.
- 2nd, The separation of the desired metal from its foreign, and principally earthy, envelope.
- 3rd, The conversion of such metal into a merchantable condition.

All these transitory processes require the influence of heat, either directly, or in its transformed character as dynamic energy or motion. And to obtain this heat we in Great Britain have recourse to fuel, which is the master-influence in almost, if not all, the *operandi* constituting the industrial procedure.

Therefore the attainment of the full thermic or heat efficiency should be a paramount axiom in all well-conducted works; because, if Nature has endowed our beloved country with a most generously proportioned gift of fuel, it is our bounden duty to do justice to this fuel by avoiding all waste, and by effecting its utilisation in such a manner as to aid Nature in her glorious actions that constitute the wonderful cycle of the conservation of energy.

Every particle of smoke or unoxidised carbon, whether as fixed carbon, carbon monoxide, or carbon combined with hydrogen as condensed hydrocarbons, and commonly associated with ammonia vapour, that is sent into the atmosphere, is a direct insult to Nature, and constitutes an action that may at some future time recoil on us with malign influence.

In many metallurgic establishments, the unintentional waste of fuel in the years of their existence must have reached a colossal figure, and the apology for this paper is adequate, if it tends to draw the attention of the members of this Institute to

the desirability of scrutinising the fuel bill, and establishing a periodic audit of the thermic or heat value introduced into the works, and the proportion of such value usefully and efficiently expended.

There should be no difficulty in securing this desideratum. For many years the foremost metallurgic establishments have had their raw material, the ores, the pig iron, the ferro-manganese, and the finished product, both chemically and physically controlled, and the extent of this control can easily be widened to include a continuous watch over the expenditure of the thermic capital introduced into the works as fuel.

It is not essential that the fuel should be analysed, except as a corroborative check; all that is required is the use of an efficient and reliable calorimeter, of durable form, the use of which can be mastered by any intelligent laboratory-assistant.

The author described the typical forms of calorimeters in his contribution to the Mathematical and Physical Section of the British Association at their Birmingham Meeting of 1885. Since then, the calorimeter recommended by the author at that time as a practical instrument, and for which we are indebted to Mr. William Thomson, F.R.S. Ed., has become, with some slight modification, a popular instrument in several engineering works and laboratories. In one London works the fuel is almost daily tested, and very fairly concordant results are obtained. The instrument (*vide* diagram, Figs. 1, 2, and 3) may be described in detail as follows:—

The essential constructional parts include:—

A graduated water-container vessel to hold a specific weight or volume of water, say 2000 c.c.

An inverted bell-glass, by which the gaseous products from the combustion of the fuel are compelled to flow or bubble through the 2000 c.c. of water, and thus relinquish their sensible heat.

A platinum crucible, to form the combustion chamber of the fuel to be tested.

An iron or steel bottle, containing a supply of compressed oxygen.

A tubular arrangement by which connection with the oxygen bottle and interior of the platinum crucible is effected, and which,

by a special rod, permits the stirring or agitation of the fuel during its combustion.

The specially graduated thermometers to register the lamp.

The other accessories include a mortar for the pulverisation or physical reduction of the fuel; a water-bath to drive off the sensible moisture; and a balance by which to weigh the fuel.

Referring to the diagrams, Fig. 1 represents a vertical sectional elevation, and that marked 2 a plan in section. Fig. 3 shows the inverted bell-glass, crucible stand, and gauze rings.

The water-container, *a*, graduated with a mark indicating a specific volume of water, say 2000 c.c., is firmly mounted on a stand, *b*, in which horizontal mercury levels, *b*¹, should be fixed, and the exact horizontal level should be adjusted by level adjusting screws, *b*².

Thermometers, *c*, are suspended from the vertical stand bar *d*.

The inverted bell-glass is marked *e*, and should be of such a capacity as not to impede combustion, and be supported on a perforated and freely porous grating or ring, *f*, which will not impede unnecessarily the flow of the products of combustion through it. This stand, *f*, is attached by a bayonet fastener arrangement to the edge of the bell.

Slipped round the outside of the inverted bell are a series of wire-gauze rings, which are intended to circulate the water and compel the uniform diffusion of the bubbles of gas through the water (see Fig. 3).

The platinum cup or crucible, *h*¹, fixed in the centre of the inverted bell, *c*, is supported on an elevated part of the inverted bell-stand, *f*, by which it is raised to the level due to the height to which the water rises in the inverted glass, when the latter is submerged so that the upper level of the crucible is above the water.

The platinum crucible is enveloped in another, and fireclay crucible.

The oxygen to support the combustion of the fuel is supplied

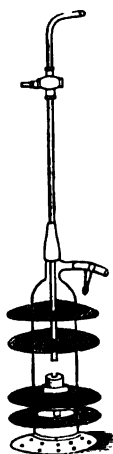


FIG. 3.

to the interior of the bell-glass by the tube *i*; moving freely in the centre is the stirrer rod *j*, which is attached at the upper end of the rod by an elastic connection, *k*. This rod is employed to stir the fuel during the progress of combustion.

The oxygen is supplied from a compressed oxygen container, *l*, obtainable from one of the now numerous oxygen-producing installations.

Special regulating valves, *m*, permit the supply of the oxygen to be nicely controlled.

The procedure is as follows:—

1st, Water is poured into the vessel up to the graduated mark.

2nd, A specific weight, say of 5 grammes, of finely pulverised and dry coal is placed in the platinum crucible, which is then deposited in the fireclay crucible placed in the centre of the stand attached to the base of the inverted bell.

3rd, All now being ready, a lighted wax vesta is dropped into the fuel in the crucible, or a strand of lamp wick may be used for ignition, the oxygen supply being gently and simultaneously turned on, and the inverted bell-glass with its crucible is gently lowered into the water in the glass vessel.

The combustion will be violently active; the gaseous products will bubble through the water, transferring the sensible heat thereto.

A small glass tube, *n*, is fixed at right angles to the tube at the top of the bell-glass; on this is attached a piece of india-rubber tube, which can be closed by a spring-clip.

After the fuel has been consumed, the opening of this tube permits the water to freely enter into the inverted bell and flow into and submerge the crucible, so that the whole of the apparatus and water is raised to a uniform temperature. The bell-glass can now be lifted up and down several times; the annular gauze rings will thoroughly agitate the water and promote equability of temperature. In order to ascertain the specific value, in equivalents of water, of the internal apparatus constituting the calorimeter, and exposed to the water, the following procedure is adopted:—

Two thousand grammes of water are poured into a vessel, and raised in temperature to 15° C. above the temperature of the

atmosphere. This water is then poured into the calorimeter, which is, of course, at the temperature of the laboratory, and which has the usual inverted bell, stand, and crucible, all *in situ*.

The water is not allowed to enter the bell-glass at first, but is repeatedly agitated by the movement up and down of the bell-glass.

The water, in transferring part of its thermic assets to the apparatus, becomes lowered in temperature; the latter will be further reduced by allowing the water to flow into the inverted glass. The procedure corresponds both in time and in manipulation to that followed in an actual test. The lowering of the temperature of the water will represent the degree of heat that will have to be allowed for in determining the calorific value. In ascertaining the amount of water to which the apparatus is equivalent, it is assumed that one-half of the difference between the temperature of the 2000 grms. of water and that of the air is equivalent to 2000 grms. of water; the result is calculated on this basis. For instance, if the atmospheric temperature in the dry calorimeter is 30°, and the water poured into the calorimeter is 35°, then, after the heat is absorbed by the apparatus from this water, it reduces the temperature to 34.5°, the equivalent of water would be measurable thus:—

$$\frac{2000 (35 - 34.5)}{\frac{35 - 30}{2}} = 400 \text{ lits.}$$

This number of grammes must be added to the weight of water used in the calorimetric estimation. The temperature of the water taken before and after the combustion of the fuel in the calorimeter will give the data by which to calculate the value of the fuel. Thus a rise of 4° C. in a sample weighing 4 grammes would give—

$$\frac{4 \times 2400}{4} = 2400$$

the thermic value of the fuel in calories.

This calorimeter enables determinations of sufficient accuracy for comparison to be performed in some ten minutes from the time the fuel is dried.

In drying the coal and in pulverising it, care must be taken not to generate or apply such a degree of heat as will volatilise the hydrocarbons, some of which are evolved at comparatively low temperatures.

The variation of results in sixteen determinations did not exceed an average of 0.75 per cent.

Comparing the results obtained by this calorimeter with the thermic values of vegetable organic matter synthetically determined by using Favre and Silbermann's factors, there is as much as 25 per cent. of difference in favour of the synthetic determination.

For coal and liquid fuels, the synthetic thermic determinations and the calorimetric ones are more concordant. In twelve determinations the difference, according to Mr. Thomson, did not exceed 1.2 per cent.

For testing liquid fuel, asbestos or pumice-stone dipped in the oils, and weighed before dipping, and before and after being placed in the calorimeter, would give the weight of oil absorbed and burnt; the oil so heated will burn in the crucible like a torch. For further details of this calorimeter, and for tables of calorific estimations by this and other calorimeters, *vide* Appendix.

The author, in a previous contribution on this subject of calorimetry, described M. Marielin Berthelot's ingenious instrument, by which this illustrious French savant and investigator has determined the thermic values of an immense number of combustible elements, both simple and complex. This instrument, like all those issuing from the hands of M. Golaz, the instrument-maker to the Institute de France, is at once a marvel of precision and delicacy; but for industrial laboratories its delicacy and cost are insurmountable objections.

Thanks to the initiative and financial aid of the Société d'Encouragement pour l'Industrie Nationale, M. Berthelot's instrument has been very materially simplified and reduced in cost by the ingenuity of M. Pierre Mahler, and Berthelot's calorimeter has now entered into the domain of the industrial laboratory, by which metallurgists and engineers can easily estimate the thermic values alike of liquid, solid, and gaseous combustible constituents.

This apparatus has recently been tested at the Ecole des

Mines before a great number of practical experts in engineering, applied chemistry, and metallurgy.

The general arrangement of M. Mahler is shown by the illustration (see Plate, fig. 4).

The combustion of the fuel is effected in a vessel, *a*, formed of superior mild steel, having a tensile strength of 55 kilos. per square millimetre of section, and having 22 per cent. of elongation. The capacity of the combustion chamber is 654 centimetres cube, the thickness of the shell is eight millimetres. The capacity is thus many times superior to that of M. Berthelot, and is provided, so as to ensure perfect combustion of the carbon, with an excess of oxygen, and to permit the calorimetric estimation of generator or producer fuel gas of comparatively inferior thermic value.

The combustion vessel is nickel-plated externally; internally it is coated with enamel to preserve the steel against the effects of nitric oxides.

The vessel has a ferro-nickel cover, to which is attached a top-plate carrying a conical valve, which permits the introduction of the oxygen.

The top plate is also traversed by a well-isolated electrode prolonged into the interior of the vessel by means of a platinum conductor.

Another suspension rod carries the capsule plate or saucer, on which the combustible element is placed.

This is ignited by the electro resistance, and also combustion of a small spiral iron wire, which burns immediately and ignites the combustible.

The method of agitating the water is similar to that introduced by Berthelot, but is less costly and much easier to work. The agitator is helicoidal, and is supported in the centre by a projecting arm, provided with a lever, by which both the horizontal and the circular movement of the agitator can be effected.

A small bichromate battery, of two amperes and twelve volts, is employed for ignition purposes.

There are the usual specially graduated thermometers; a pressure gauge to indicate pressures up to 150 atmospheres, and the bottle of compressed oxygen, complete the calorimetric equipment, *per se*.

The usual drying, pulverising mortar, and weighing apparatus are of course required.

An oxygen bottle containing 1200 litres at a pressure of 120 atmospheres provides enough oxygen for 100 tests.

The procedure of determination is as follows:—

The fuel is weighed as before. The small spiral wire, of a predetermined weight, is attached to the end of the electrode. The fuel is placed in the platinum dish or saucer, and then lowered into the combustion vessel, and the cover of the vessel is firmly secured by a spanner. The oxygen supply connection is now made, and the oxygen is allowed to enter until the pressure on the gauge indicates 25 atmospheres; the oxygen regulator is then closed, as well as the needle-valve of the oxygen connection.

It is not advisable in this calorimeter to pulverise the fuel too finely, and the oxygen must be allowed to enter the vessel not too violently, otherwise the fuel may be blown off the dish or saucer.

The combustion vessel is now placed in the calorimeter.

The water is poured into the central vessel and into the external annular chamber. The water is now agitated to obtain uniformity of temperature.

The temperature of the water is carefully observed, as well as that of the atmosphere of the laboratory, every minute during an interval of five minutes before igniting.

The ignition is now effected by the connection of electrodes to the conductors of the battery. Combustion is effected instantly.

The temperature is noted half a minute after ignition, then at the end of the minute, the observations being continued until the temperature shows signs of declension; this indicates the maximum thermic influence.

The temperature observation is continued for a period of another five minutes.

The agitator of the water must be continually worked during the observation period.

The data for calculation is now *en evidence*, particularly that to enable the estimation of the only correction required—*e.g.*, the correction due to the loss of heat by the calorimeter during the test.

This loss can be calculated by the acceptance of the following statement:—

1st, The law of the descent of the temperature absorbed after

the attainment of the maximum degree, represents the loss of heat from the calorimeter, and before the attainment of the maximum, for say a period of one minute, on the condition that the mean temperature during this minute does not differ more than 1° from the maximum temperature.

2nd, If the temperature of the minute period under consideration differs more than 1° C., but less than 2° , from that of the maximum, the figure representing the law of descent at the moment of the maximum, diminished by 0.005, gives the required correction.

The acknowledgment, according to M. Mahler, of these two statements of definition will satisfy all the correction required. It must, however, be understood that the law of variation subsequent to the first half of the minute after the ignition, is that which exists at the moment of minimum variation.

After the observations are completed, the combustion vessel is removed and washed out with a known volume of water, to recover the acidulous liquor formed during combustion.

The hydric nitrate (NO^5HO) is dosed acidimetrically.

The definition of the thermic value of the fuel can now be determined.

Where Δ = the difference for corrected temperature.

W = weight of water of the calorimeter.

W^1 = the equivalent in water of the apparatus (of the calorimeter) exposed to and acquiring the temperature of the water.

n = the weight of the hydric nitrate (NO^5HO) ascertained.

f = the weight of the spiral of iron.

0.23 = the heat of formation of 1 gramme of dilute nitric acid.

1.6 = the heat of combustion of 1 gramme of iron.

x = the calorific power of the combustible tested.

Then $x = \Delta (W + W^1) - (0.23p + 1.6f)$.

It is unnecessary to take into account the minute quantity of SO_2 produced; but if its value is required to be determined, 2 grammes of fuel should be used under a pressure of 30 atmospheres.

The sulphur is, of course, oxidised to SO_2 .

The formation of SO_3HO disengages 0.73 calories per gramme of SO_3HO .

The Calorimetric Estimation of Fuel Gas.

The application of the Berthelot-Mahler calorimeter to determine the thermic value of fuel gas is as follows:—

The combustion vessel is immersed in water for the purpose of evacuating the air, the vessel is then filled with gas and emptied, and again definitely refilled with gas at the barometric pressure and temperature of the laboratory.

The oxygen is then added, and the calorimetric procedure described for solid fuel is followed.

Note.—The pressure of oxygen for retort or town gas must not be allowed to exceed five atmospheres, whilst for generator or producer fuel gas a pressure of half an atmosphere will be adequate, and should not be exceeded.

In order to exactly determine the value of W^1 in the equation, the following simple and easy procedure must be twice repeated:—

A given weight, say 1 gramme of a combustible composition of a known character, such as naphthalene, for example, is burnt in the calorimeter, in which there is say 2,300 grammes of water.

Afterwards a less weight, say 0.8 gramme of naphthalene, should be burnt with 2,100 grammes of water in the calorimeter.

We have now two equations by which the heat of the combustion of the naphthalene, and from this the value of the equivalent of water, may be deduced.

Here is an example of a determination given by M. Mahler.

The tested fuel had the following character:—

Carbon	77.182
Hydrogen	11.711
Oxygen and nitrogen	11.107
	100.000

The weight of fuel equalled 1 gramme.

The calorimeter was supplied with 2,200 grammes of water.

The equivalent in weight of water of the apparatus W^1 of the calorimeter is taken at 481 grammes.

This equivalent of water has been definitely adopted by M. Mahler. His determination was effected by a special method, giving directly the specific heat of the system.

In the calorimeter exhibited, W^1 equals 370—the structural details being much lighter.

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N

After the ignition of the fuel by the connection with bichromate battery, the temperature was noted as follows:—

Period of Combustion.

5½ minutes	10·80 degrees.
6 "	12·90 "
7 "	13·79 "
8 "	13·84 " maximum registered temperature.

Period posterior to Combustion.

9 minutes	13·82 degrees.
10 "	13·81 "
11 "	13·80 "
12 "	13·79 "
13 "	13·78 "

$$\Delta = \frac{13.84 - 13.78}{5} = 0.012$$

The observations are now completed.

The variation of the temperature has been—

$$13.84 - 10.25 = 3.59.$$

We can now ascertain the extent of the correction which must be recognised.

The procedure has involved the thermic loss during the minutes 7·8, 6·7 of a quantity of heat equivalent to the law of maximum cooling—

$$\frac{13.84 - 13.78}{5} \times 2 = 0.12 \times 2 = 0.024$$

During the half minute, 5½ to 6, there has been a thermic loss represented by $(0.12 - 0.005)\frac{1}{2} = 0.0035$, and dividing the half minute, 5 to 5½ (the law of minimum cooling) thus—

$$\frac{10.25 - 10.23}{5} \times \frac{1}{2} = 0.004 \times \frac{1}{2} = 0.0020$$

Consequently the relative loss of the minute 5·6 equals—

$$0.0035 - 0.002 = 0.0015.$$

Consequently the calorimetric procedure has involved the thermic loss, pending the duration of the experiment, corresponding to

$$0.024 + 0.0015 = 0.0255.$$

The amounts to be added to the 3·59° already noted.

The variation of temperature, neglecting the 10 millimetres, is thus equal to 3·615.

The thermic or heat value absorbed is consequently—

$$(2,200 + 481) \times 3\cdot615 = 9\cdot69181 \text{ cal.}$$

To obtain the exact figure we must subtract from the determined value,—first, the heat of formation of 0·13 gramme of hydric nitrate (NO_2HO) volumetrically diluted, thus—

$$0\cdot13 \times 0\cdot23 = 0\cdot0299 \text{ cal.}$$

Second, the heat of combustion of the iron, weighing 0·025 grammes. Then—

$$0\cdot025 \times 16 = \frac{0\cdot0400 \text{ cal.}}{0\cdot0699 \text{ cal.}}$$

The final result is therefore—

$$9,691\cdot8 \text{ cal.} - 0\cdot0699 \text{ cal.} = 9,621\cdot9 \text{ cal.}$$

or for a kilometre of oil = 9,621 cal.

Compared with the synthetically calculated values, using Favre and Selbermann's co-efficients, the estimation with the Berthelot-Mahler calorimeter, by the procedure indicated, gives very concordant results.

Many useful thermic determinations have been effected with the Berthelot-Mahler, the Thomson, and other calorimeters, some of which are enumerated in the appendix.

The author some years back suggested that, in determining the relative values of different coals in settling contracts, the calorimetric test should be respected if not followed.

The test value is more direct and reliable than that deduced from an analysis, however carefully performed; and the author is of opinion that were coal supply contracts settled on the basis of calorimetric unit value, in the same way that ferro-manganese, iron ore, and other raw materials are purchased, a very considerable economy might result.

Further, seeing that in the most progressive works the absorption of dynamic energy of each machine is tested for comparison with a dynamometer, he does not see why furnaces should not be compared as to their thermic efficiency. The relation of weight of fuel used to output, and the continuous record of the chimney temperature, might be the data to draw the comparison and to deduce the thermic efficiency.

The author is indebted to M. Golaz, of Rue St. Jacques, Paris, for the loan of the Berthelot-Mahler pyrometer, which has been made especially for this meeting.

The Berthelot-Mahler pyrometer has been adopted by the École Polytechnique of Carlsruhe and by the Boston (U.S.) Technical School.

The author and the Institute are also indebted to Messrs. F. A. Jackson & Co., of Manchester, for the loan of the Thomson calorimeter.

PART II.

NOTES ON A NEW OPTICAL PYROMETER.

The foregoing short exposé of methods of calorimetrically determining the heat value of fuel, may not be inappropriately terminated with a reference to a system of determining the intensity of elevated temperatures of quite different form to that of the air pyrometers introduced by Berthelot, and recently further developed by Wiborgh. Since the date when our illustrious ancestor Wedgwood invented the first practical pyrometer, based on the contraction principle, scientists and metallurgists have sought, with interminable efforts, for an instrument which, without being too delicate or too complicated, should register with fair accuracy the degree of intensity of elevated temperatures, with what success most metallurgists are thoroughly well aware of. Instruments, like the air-pyrometer of M. Marielin Berthelot, coming from the hands of M. Golaz, and conducted under the generous financial influences of the Institute of France, are available, and have been used for the determination of important facts in the branch of the pure science of thermo-chemistry; but instruments of such refined precision are altogether unfitted for the industrial laboratory. The thermo-couple of M. Le Chatelier, which the author had the honour to introduce to the notice of English engineers some years ago, is, however, better adapted for industrial determinations, and by its use important molecular phenomena have been discovered, as well as thermic data of considerable value to future investigators; nevertheless, this instrument is still too delicate in structural character for ordinary industrial laboratory usage, and to-day it may be safely asserted that, in metallurgic establishments,

the temperature is determined more or less approximately by recourse to other and physical test indications, and to the ocular judgment of furnacemen.

Of course, for temperatures below 700°C. , there are pyrometric instruments, such as those of Murrie, Siemens, Gauntlett, and others, which are more or less sufficiently accurate; but, for elevated temperatures, ranging above 1000°C. , we have not had the instrument that could be considered at all fitted for the ordinary industrial laboratory and for daily use, and this fact is the apology the author has to offer to the members of the Institute for introducing to their notice the new optical pyrometer, which is the result of considerable research and experimental effort on the part of M. H. Le Chatelier and M. Cornu.

We all know the difficulties that face the adequate solution of this question of high temperature determination.

Exposed to the disintegrating influences of intensely active thermo-chemical actions, due to elevated temperatures, how can we expect any instrument to withstand, unaffected, the exposure to conditions to which, in some degree, all elements are subjective?

And the only form or character of agent that can be continuously relied upon is that which is independent of actual or intimate contact with the thermic influences whose intensity is to be determined.

The principle of testing the temperature of metal by the eye is observed in most steel and iron works; and, for our thermic calculations, we have hitherto taken the temperatures of fusion, &c., as defined by Pouillet and others, corresponding to the different colours emitted as rays from incandescent bodies; for instance, the temperature determinations here given are arbitrarily associated with the colours indicated.

	Deg. Cent.
Red-heat corresponds to	525
Cherry red "	800
Orange tint "	1100
White "	1300
Dazzling white "	1500

But such determinations are untrustworthy; and, although the method is convenient, it does not accord with our ideas of accuracy.

The first development of pyrometry based on this system is due to Messrs. Nouel and Mesuré.

Their arrangement consisted of a happy combination of a piece of quartz placed between two pairs of Nicol prisms, in the optical tube of a spy, or telescopic glass, provided with lens for observing the incandescent object. By the influence of these prisms and the quartz, the mean radiations of the spectra are absorbed, and by the simple rotation of the prisms the successive colours can be defined. The angle of rotation, identified by a graduated circle, and necessary to eliminate the red rays, varies with the temperature, and consequently this law is the basis of the measurement. Unfortunately, the results are only widely approximative.

In the new Cornu-Le Chatelier optical pyrometer, the estimation of elevated temperatures is determined by the utilisation of the absolute measurement of the intensity of a specific luminous radiation.

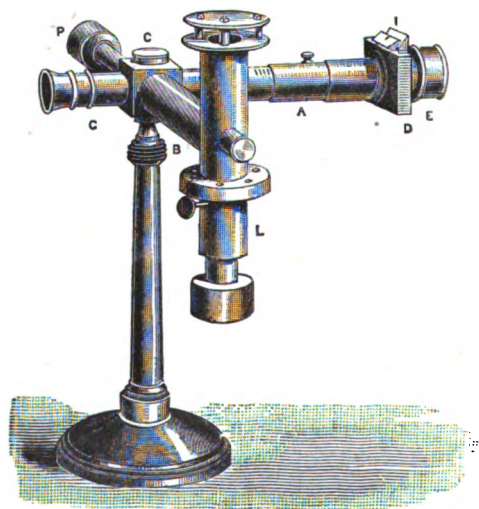


FIG. 5.—THE CORNU-LE CHATELIER PYROMETER.

This conception has been the ideal one of MM. Becquerel, Violle, and others; but it has been left to M. Le Chatelier (using M. Cornu's photometer) to practically apply, and successfully develop, this beautiful principle. Certain thanks are also due to M. L. Appert, of Clichy-Levallois, and M. Pellin, the optical instrument maker. The instrument is shown by Figs. 5 and 6.

The difficulty that occurs in the use of this principle for closely

accurate determinations is the variation of the emissive power of different bodies. It is pretty certain that the intensity of the radiations emitted from an incandescent body are not merely dependent upon its temperature, but depend also upon the particular nature of the body and its surface—but, as in the instance of two such strikingly physically different bodies as are iron and brick, the emission factor only varies $\frac{1}{100000}$ th part, this difficulty for all industrial determinations can safely be ignored.

The Cornu photometer has been adopted by M. H. Le Chatelier, and enables a perfect comparison to be made between the incandescent object (whose temperature is to be determined) and the luminosity of the flame of an acetate of amyl-lamp.

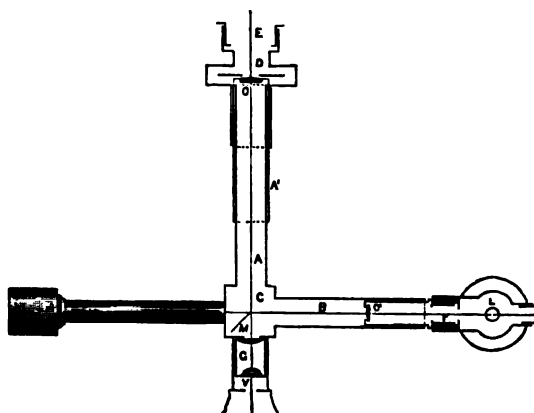


FIG. 6.

The only care required is the initial adjustment. Once this is satisfactorily effected, the instrument is appropriate to, and suitable for, industrial thermic investigations, and for the control of temperatures; and the instrument will, the author trusts, be welcomed into the laboratories of metallurgists and others. The author has added more complete data in the Appendix (*vide* page 211).

The author, and the Iron and Steel Institute, are under obligations to M. H. Le Chatelier, and M. Pellin, of 21 Rue de l'Odeon, Paris, for the loan of the exhibited photometer, which has been especially made for this meeting.

The third and subsequent part of the subject of this paper will be read at the next meeting of the Iron and Steel Institute.

APPENDIX.

CALORIMETRIC VALUES.—THOMSON'S CALORIMETER.

ANALYSES OF COAL.

	Nixon's Navigation Collieries, Glam.	Thakerley Collieries, Tyldesley.	Tyldesley Coal Co.	"Upper Drumgray Seam."			Bickershaw Collieries, Leigh, near Manchester.					A. Knowles & Co.'s Colliery.	
				Bottom.	Hard Mid-rth.	Top Part.	Bicker- shaw. Main.	Pen- berton. 5 ft.	Crom- bourne.	Wigan. 4 ft.	Bicker- shaw. 7 ft.		
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Pendle- ton. 4 ft.
Volatile matter	11.722	30.103	32.085	25.633	24.264	27.553	29.809	32.287	31.666	28.314	31.228	28.527	
Fixed carbon	84.046	50.276	57.755	65.037	60.899	64.629	63.870	56.464	57.871	64.099	61.212	65.661	
Ash	3.216	14.902	4.086	6.549	12.576	4.286	1.961	4.550	3.313	2.749	.960	1.912	
Moisture	1.016	4.719	6.074	2.781	2.261	3.532	4.360	6.699	7.150	4.838	6.600	3.900	
	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	
Coke.	87.262	65.178	61.841	71.586	73.475	68.915	65.831	61.014	61.184	66.848	62.172	67.573	
Total sulphur	.787	1.619	.646	.749	.543	.862	1.066	1.021	1.449	1.238	.699	.629	
Fixed sulphur	.098	.230	.154	Absent	Absent	Absent	.025	.089	.283	.171	.018	.040	

DESCRIPTION OF COAL.											
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Nixon's Navigation Collieries, Glam.	Thakerville Collieries, Tyldesley.	Tyldesley Coal Co.	"Upper Drumgray Seam."			Bickershaw Collieries, Leigh, near Manchester.					
			Bottom of Seam.	Hard Mid-rib.	Top of Seam.	Bicker-shaw. Main.	Pem-berton. 6 ft.	Crom-bourke.	Wigan. 4 ft.	Bicker-shaw. 7 ft.	Pendle-ton. 4 ft.
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
88.029	68.194	74.464	76.484	72.190	76.049	78.930	72.409	69.774	76.487	73.913	79.760
4.112	4.777	5.105	4.982	4.672	5.123	4.904	5.168	4.819	4.964	4.868	4.893
1.977	4.861	8.251	7.865	6.565	9.391	7.239	8.844	12.445	8.468	11.320	7.517
.961	1.218	1.228	1.590	1.253	1.757	1.565	1.408	1.353	1.437	1.668	1.426
.689	1.389	.492	.749	.543	.852	1.041	.932	1.166	1.067	.681	.589
3.216	14.902	4.086	6.949	12.576	4.286	1.961	4.550	3.313	2.749	.960	1.912
1.016	4.719	6.074	2.781	2.261	3.532	4.360	6.689	7.150	4.838	6.600	3.900
100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
98.079	78.990	89.348	89.921	84.620	91.320	92.638	87.819	88.371	91.346	91.759	93.599
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
92.586	86.257	83.342	83.945	86.240	82.182	86.203	82.463	78.956	83.733	80.531	86.215
4.325	6.047	6.713	6.541	5.521	5.610	5.294	5.873	6.453	5.434	5.294	5.237
1.011	1.542	1.710	1.768	1.481	1.924	1.689	1.603	1.508	1.574	1.818	1.527
2.079	6.154	9.235	8.746	7.758	10.284	7.814	10.071	14.063	9.269	12.337	8.031
100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
8.340	6.448	7.069	7.384	6.954	7.533	7.465	7.242	7.456	7.552	7.417	7.736
8.459	6.972	7.430	7.493	7.166	7.443	7.778	7.267	6.787	7.549	7.176	7.819

Caloric power :-

Found by experiment . . .

Calculated . . .

Total organic matter . . .

Which is composed of :-

Carbon . . .

Hydrogen . . .

Nitrogen . . .

Oxygen . . .

THOMSON CALORIMETER.

Referring to the Thomson calorimeter, and to the equivalent weight of water corresponding to the materials exposed to the action of, and absorbing part of the heat of, combustion in this pyrometer, this equivalent value may be calculated from the weight of the parts constituting the calorimeter multiplied by the specific heat.

For the specific heat of the brass tubes, gauze, &c., take	.	.	0.0939
" " " glass, "	.	.	0.1977
" " " platinum, "	.	.	0.324
" " " indiarubber, take	.	.	0.200

With these factors the equivalent of water of the apparatus, in one example, realised 68 grammes. The following are details of another example in which the equivalent weight of water equalled 72.82 grammes.

Material used.	Weight in Grammes.	Specific Heat of Material.	Equivalent to Grammes of Water.
	Per cent.	Per cent.	Per cent.
Glass of beaker	221.472	0.1977	43.784
Glass bell	48.015	0.1977	9.492
Brass	106.017	0.0939	9.956
Iron	12.993	0.11379	1.478
Platinum	7.3496	0.0324	0.238
Clay supports	16.875	0.1977	3.336
Indiarubber	1.184	0.2000	0.237
Mercury	27.192	0.0333	0.905
Thermometer glass	4.161	0.1977	0.822
Copper gauge	27.122	0.09515	2.581
Water employed	...	...	2000.000
Equivalent total value in grammes of } water	...	...	2072.829

The practical method, already described, of ascertaining the equivalent of fall of temperature, is much better and more reliable.

As an example of calculations with the Thomson calorimeter, let us assume that immediately after the combustion of the fuel is completed the temperature of the water has been increased by 3.50°C . Then the calorimetric value will be equal to $3.50 \times 2072.829 = 7254.9$ calories. To obtain the evaporation value of this fuel, we will divide by Berthelot's latent heat of

vaporisation factor, 636; thus, $\frac{7254.9}{636} = 11.4$, so that 1 kilo. of this fuel that will raise the 2000 grammes or cc. of water 3.50° C., will evaporate 11.4 kilos. of water at atmospheric pressure.

Additional precautions are to be observed during the procedure of determination with the Thomson calorimeter.

The Oxygen Supply.—It is advisable to connect the compressed oxygen cylinder to a small gas-holder, weighted to give only a slight pressure. This gas-holder should be connected to a water supply. The introduction of the water displaces the oxygen, and in proportion as the water is introduced, so is the oxygen forced into the inverted bell-glass of the calorimeter. A closed water-gauge fixed outside the gas-holder shows the contained volume of oxygen. An ordinary U water-tube shows the pressure of the gas in the holder.

The Combustion.—It will be noticed that the coal burns gently at first. The oxygen introducing-pipe should not be projected too low into the inverted bell-glass until the volatile hydrocarbons are oxidised or burnt off.

After the volatile hydrocarbons have been completely evolved, the residual skeleton of fixed carbon or coke is more difficult to burn; the oxygen supply-tube should consequently be projected so as to deliver the oxygen immediately over the platinum crucible, and to more effectually burn the fuel the oxygen supply-tube may be slightly rotated. When the fuel is consumed, the tap of the supply-pipe from the oxygen container is closed, and the connection between calorimeter and gas-holder broken, so that the residual gas can be allowed to escape. The evacuation of the gas being promoted by the flow into the invert glass of the surrounding water—which encloses and covers the crucible—and other parts of the apparatus, from which the residual heat is absorbed, so that the whole of the apparatus and water are raised to the same temperature.

The invert bell-glass and crucible can now be withdrawn, and the temperature taken.

The volume of oxygen employed is determinable by the water-gauge of the holder, and for greater accuracy the volume of the oxygen gas, plus that due to the combustion, can be calculated, and the heat absorbed and abstracted by these gases can be found.

But knowing that the weight of oxygen used for a single determination should not exceed 10 grammes, and the range of temperature of the operation does not attain a greater difference than 5° , the correction due to the abstraction of heat, as sensible heat, is too little to deserve serious consideration.

When great accuracy is required, the author recommends, without reserve, the Berthelot-Mahler calorimeter.

For very many practical purposes, however, the Thomson calorimeter gives determinations of sufficient accuracy.

COAL.—TABLE I.]
 CONSTITUTIONAL AND CALORIMETRIC VALUES.
 BERTHELOT-MAHLER CALORIMETER.

Character of Combustible.	Elementary Analysis.						Volatile Matter after the Evaporation of Water.	Calorific Value.	
	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Hygroscopic Water.	Residuum.		Directly Observed.	Deducting Water and Ash.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.		
Long-flame coal, Ste. Marie (Blanz)	79.387	4.967	8.725	1.13	3.90	1.90	30.10	7,865.8	8,350
Commentary gas-coal . . .	80.183	5.245	7.193	0.98	3.00	3.40	37.40	7,870.4	8,408
Lens gas-coal . . .	83.727	5.216	6.007	1.00	1.05	3.00	29.55	8,395	8,744
Bituminous coal of Treuil (Sainte Etienne)	84.546	4.772	4.593	0.84	1.25	4.00	19.75	8,391.7	8,856
Semi-bituminous coal from the Saint Marks pits (Anzin)	88.473	4.139	3.158	1.18	1.35	1.70	13.65	8,392.5	8,656
Japanese anthracite coal . . .	85.746	2.723	2.671	0.60	2.80	5.45	4.56	7,828.1	8,532
Pennsylvanian coal . . .	86.456	1.985	1.449	0.75	4.45	5.90	2.75	7,484.4	8,256
OIL.—TABLE II.									
Coke left after distillation of American petroleum . . .	97.855	0.489	1.196	0.26	...	0.20	...	8,057.2	8,073
Heavy oil from American petroleum . . .	86.894	13.107	0.203		...	...	...	10,912.7	10,912
Refined American petroleum . . .	85.491	14.216			...	...	...	11,045.7	...
Treble refined American petroleum . . .	80.583	15.101			...	...	...	11,086	...
Grade American oil . . .	83.012	13.389			...	...	...	11,094.1	...
Heavy Baku oil . . .	86.700	12.944	...	...	...	0.35	...	11,804.6	10,842
Novorossiask petroleum, Caucasian . . .	84.906	11.686	...	9.458	...	...	...	10,328	...

GAS, TAR, AND COKE—TABLE III.]

DETERMINATIONS WITH THE BERTHELOT-MAHLER CALORIMETER.

Character of Combustible.	ELEMENTARY ANALYSIS.						Observed Caloric Power.	Weight of Residual Coke, &c., after Dis- tillation of 100 Kilogrammes of Coal.	Heat disengaged by the Products of the Distillation.
	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Clnders.	Water.			
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.			
Gas-coal from the Commentary pits	75.182	5.176	8.202	0.94	7.05	3.45	Calories. 7.4232	Kilogrammes. 100	Calories. 742,326
Coke, from the Commentary coal	85.773	0.414	2.043	0.62	10.27	0.88	7.0194	Per cent. 65.66	460,892
Tar, from hydraulic main .	89.910	4.945	5.145	...	...	...	8.9428	0.87	7,780
Tar from cooler	87.222	5.499	6.279	...	...	...	8.8310	1.16	10,243
Tar from condenser . . .	85.183	5.699	9.218	...	...	...	8.5384	1.89	16,137
Gas from the coal	55.086	21.460	23.454	...	...	...	11.1110	17.09	189,887
Ammoniacal water . . .	...	...	...	14.7 grms. per litre	...	...	...	9.36	...
Thermic value lost in calories .	...	...	...	...	...	...	...	99.62	716,846
Coke employed in the distilla- tion	...	...	...	...	...	...	...	...	25,479
	...	...	...	...	...	...	...	21.09	148,063

TABLE IV.—GLASS FURNACE FUEL GAS.]

CALORIMETRIC DETERMINATIONS WITH THE BERTHELOT-MAHLER
CALORIMETER.

General Constitution.	
Formene . . . 2 per cent. Hydrogen . . . 12 " Carbon monoxide 21 " Carbon dioxide . 5 " Nitrogen . . . 60 "	} Calorimetric value of a cube metre = 1112 calories.

TABLE V.—COAL GAS.]

Coal Gas.	Calorific Power, calorimetrically determined, of 1 Cubic Metre.	Density.	Calorific Value of 1 Kilo- gramme.
	Calories.		Calories.
Distributing gas from the gas-works of La Villette }	5,601.9	0.4033	10,744
Commentry coal gas }	5,804	0.404	11,111
Cannel coal gas }	6,365.5	0.6367	7,735

CALORIMETRIC VALUES WITH THE BERTHELOT CALORIMETER.

	Calories pro- duced by the Combustion of 1 Litre of the Vapour of the Combustible.	Calories pro- duced by the Combustion of 1 Gramme of the Combustible.	Relative Value Burnt in 1 Litre of Oxygen.	Relative Value Burnt in 1 Gramme of Oxygen.
Carbon	3,929	7,295	3,929	2,735
Hydrogen, H	3,106	34,601	6,212	4,325
Marsh gas, CH ₄ . . .	9,587	13,350	4,793	3,337
Carbon monoxide, CO .	3,130	2,490	6,260	4,358
Ethylene	15,338	12,203	5,113	3,560
Absolute alcohol . . .	14,375	6,962	4,792	3,336
Turpentine	70,607	11,567	5,043	3,611
Olive oil	...	9,862	...	...
Ether	31,335	9,431	5,256	3,659
Sulphur	...	2,601	...	...
Iron	...	...	6,216	4,327
Tin	...	...	6,508	4,531
Copper	...	...	3,722	2,591
Antimony	...	...	5,484	3,818
Zinc	...	...	6,577	5,275
Cobalt	...	...	5,721	3,983
Nickel	...	...	5,323	3,706

TABLE OF CONSTITUTIONAL AND CALORIMETRIC VALUES.

GRÜNER.

Character of Coals.	Elementary Composition.			Products of Dry Distillation.			Gaa.	Caloric Power.
	Carbon.	Hydrogen.	Oxygen and Nitrogen.	Coke.	Ammoniacal Water.	Hydrocarbon Tar.		
Dry coal	Per cent. 90-93	Per cent. 4·5-4	Per cent. 5·5-3	Per cent. Pulverulent, 82-90	Per cent. 1-0	Per cent. 6-2	Per cent. 12-8	Calories. 9200-9600
Rich and hard coal	88-91	5·5-4·5	6·5-4·5	Large coke, 74-82	1-1	10-5	15-12	9300-9600
Smithy coal.	84-89	5-5·5	11-5·5	Large coke, 68-74	3-1	13-10	16-15	8800-9300
Long-flame rich bituminous coal .	80-85	5·8-5	14·2-10	Agglomerate, 60-68	5-3	15-12	20-17	8500-8800
Lean coal	75-80	5·5-4·5	19·5-15·5	Calcined coke, 50-60	12-5	18-15	20-20	8200-8300
Dry lignite	65-75	6-4	29-21	Charcoal, 40-50	20-15	16-14	24-21	6480-6891

CALORIMETRIC DETERMINATIONS OF GENERATOR GASEOUS FUELS.

Character of Gas.	Composition.	Per cent.	Calorific Value per Litre, Calories.
Generator gas from wood charcoal.	Nitrogen . . .	64.9	1,120
	Carbondioxide . . .	0.8	
	Carbonmonoxide . . .	34.1	
	Hydrogen . . .	0.2	
		100.0	
Generator gas from wood.	Nitrogen . . .	55.2	1,156
	Carbondioxide . . .	11.6	
	Carbonmonoxide . . .	34.5	
	Hydrogen . . .	0.7	
		100.0	
Generator gas from peat.	Nitrogen . . .	63.1	0,547
	Carbondioxide . . .	14.0	
	Carbonmonoxide . . .	22.4	
	Hydrogen . . .	0.5	
		100.0	
Generator gas from coke.	Nitrogen . . .	64.8	1,131
	Carbondioxide . . .	1.3	
	Carbonmonoxide . . .	33.8	
	Hydrogen . . .	0.1	
		100.0	

CALORIMETRIC VALUES.

Nature of Combustible.	Composition.				Calorific or Thermo Value.
	Carbon.	Hydrogen.	Oxygen and Nitrogen.	Hygrometric Water.	
	Per cent.	Per cent.	Per cent.	Per cent.	Calories.
Cellulose . . .	44.4	6.17	49.39	...	3,622
Ordinary wood . .	39.0	ash	20.0	40	3,652
Coal from the pits of Chaptal Creusot .	88.48	4.41	7.1	...	9,622
Petroleum from Ovestern, Virginia .		13.9	0.8	...	10,104

CLASSIC CALORIFIC VALUES—SIMPLE BODIES.

Units of Weight per Gramme.

FAVRE AND SILBERMANN.

Combustible.	Calories
Hydrogen oxidised to H_2O	34,462.0
Hydrogen chlorinated to HCl	23,783.0
Wood carbon	8,080.0
Graphite carbon	8,047.0
Natural graphite	7,796.6
Graphite from blast furnaces	7,762.3
Native sulphur	2,261.8

1892.—i.

0

CALORIMETRIC VALUES.

SCHEURER-KESTNER—WALTHER MEUNIER.

Constitution.		Calorific Value.	Designation of Coals.
		88.48	9622 { Creusot coal.
		4.41	
		7.11	
		<u>100.00</u>	
Carbon (C)		88.32	9077 { Ronchamp rich bituminous coal.
Hydrogen (H)		4.79	
Nitrogen and oxygen (O & N)		6.81	
		<u>100.00</u>	
		81.56	8462 { Saarbrück rich bituminous coal.
		4.98	
		13.46	
		<u>100.00</u>	

CALORIFIC VALUE—BLAST FURNACE GASES.

SCHERER.

Constitution.		Calorific Value per Litre, Calories.	
		63.4	Charcoal. 1,078
		5.9	
		29.6	
		1.0	
		0.1	
		...	
		<u>100.0</u>	
Nitrogen (N)		64.4	Coke. 1,157
Carbondioxide (CO ₂)		0.9	
Carbonmonoxide (CO)		34.6	
Marsh gas (CH ₄)		...	
Hydrogen (H)		0.1	
Olefiant gas (CnH ₂)		...	
		<u>100.0</u>	
		56.3	Coal. 1,336
		15.2	
		21.5	
		4.2	
		1.0	
		1.8	
		<u>100.0</u>	

THE CORNU-LE CHATELIER OPTICAL PYROMETER.

The photometer employed is a modification of the one introduced by M. Cornu, and consists essentially of a telescope associated structurally with a standard of comparison oil-light lamp.

The flame image of this lamp is projected upon a mirror, fixed at an angle of 45° , and placed internally across the junction of the tube-branch of the lamp with that for sighting the incandescent object to be tested.

The intensity of the luminous beam, projected from the oil-lamp flame, and that issuing from the furnace, or other heated and incandescent object, whose temperature is required to be determined, is equalised, and the degree of adjustment required to effect this equalisation enables the temperature to be determined.

Referring to Figs. 5 and 6, see pp. 198, 199, showing respectively an elevation and plan in section of the instrument, the telescope comprises an object-glass O, before which there is a diaphragm aperture or stop D. The adjustment of this diaphragm aperture by the mounting E, permits the intensity of the luminous beam from the furnace to be equalised with that from the oil lamp. In instances of extremely high or exceptionally dazzling intensity, tinted glasses can be fixed in the mounting E, by which the intensity of the luminous beam is modified to agree with that projected from the oil-lamp of comparison.

The mirror M is fixed across the object-tube at an angle of 45° , in such a way that the luminous beam projected by an intermediate lens, O', from the oil light of comparison, can be compared with the luminous beam issuing from the incandescent object whose temperature is to be determined. An eye-piece C, before which there is placed, in a fixed position, a mono-chromatic red-tinted glass, K, serves for the purpose of observation of the zone of incandescence of the furnace, or other object to be pyrometrically tested.

Near the oil lamp there is fixed another and rectangular set of diaphragms or stops, F, similar to those fixed before the lens O, on the object tube. They serve for fixing the height of the oil flame, and for intercepting the extraneous rays.

The diaphragm F carries a mounting intended for the reception of the tinted absorbing glasses.

In order to measure the intensity of heat of any incandescent body, the following is the procedure to be adopted.

1. The same character of petroleum oil should be used ; a good stock of oil should therefore be kept.

2. The height of the flame should remain constant.

3. The luminous beam projected from the lamp should be divided into two equal parts by the edge of the mirror M. This can be realised by turning the lamp on its mounting.

4. Before attempting to define a temperature, ten minutes must be allowed from the time of lighting the lamp until the latter has attained its normal luminous intensity. See Figs. 5 and 6.

In order to take a measurement, the object glass is turned on to the furnace or other incandescent surface to be tested, in such a way that its image is cut in equal divisions by the edge of the mirror, and is thus brought into contact with the image projected from the light of the oil lamp. The opening of the shutter diaphragm aperture, and the variation of the intensity of the beam projected from the incandescent surface, is effected by turning the screw knob on the object telescope, so that, by this means, the equality of intensity of the two images is established.

If n is the number of divisions read upon the graduated scale fixed on the tube of the object-glass, and indicating the degree of adjustment of the shutter diaphragm of the lens O, and n^1 is the number of divisions obtained on sighting the source of light taken as a standard for comparison (say the light given by a spermaceti candle, or that of a paraffin, pentane, or acetate of amyl lamp), the intensity of heat sought for will be found by the formula—

$$\left(\frac{n^1}{n}\right)^2 = I. \text{ (intensity of heat).}$$

In other words, the intensity is equal to the inverse ratio of the superficies of the opening of the shutter diaphragm aperture fronting the lens, O.

If the objects sighted are not at equal distances—that is to say, if the areas of incandescence to be observed are at different distances—the intensity of the formula involves the following

modification, in which f and f^1 are respectively the *focal* distances of the incandescent objects.

Then

$$\left(\frac{n^1}{n}\right)^2 \times \left(\frac{f}{f^1}\right)^2 = I. \text{ (luminous or heat intensity).}$$

Further, should it be necessary to have recourse to the employment of coloured or tinted light absorbing-glasses for the proper adjustment of the luminous intensities, the co-efficient of absorption of these coloured glasses should be determined.

To enable this to be done, an object of appropriate luminous intensity is sighted with the object-lens by interposing the tinted absorbing-glass before the shutter diaphragm aperture, E .

Let n be the degree of opening of the shutter diaphragm aperture without the tinted absorbing-glass, and n^1 the degree of opening of shutter with an absorbing-glass. The co-efficient of absorption of the coloured glass will then be found by the formula—

$$\left(\frac{n^1}{n}\right)^2 = K.$$

In a determination made with a specific number, p , of these tinted absorbing-glasses, the intensity will be found by the formula—

$$\left(\frac{n^1}{n}\right)^2 \times \left(\frac{f}{f^1}\right)^2 \times \left(\frac{1}{K}\right) p.$$

If the character of the incandescent object to be measured is such as to emit very few luminous rays, the tinted absorbing-glasses must then be made to intercept the luminous beam projected from the oil light of the lamp of comparison, by being placed in the mounting F of the rectangular diaphragm.

The intensity is measurable by the formula—

$$\left(\frac{n^1}{n}\right)^2 \left(\frac{f}{f^1}\right)^2 K p.$$

By a simple adjustment, the pyrometer can be utilised for the determination of the temperature of very small objects, such as the temperature of the filament of an incandescent electric lamp, or the temperature of a steel tool or watch-spring requiring to be tempered.

The graduation of each instrument can be made by means of the following table, which gives for different temperatures the intensity of the red-rays (determined by taking as unity the intensity corresponding to the most luminous part of the axial zone of the flame of a candle):—

Temperatures in Degrees Centigrade.	Intensities.
600	0·00008
700	0·00075
800	0·0046
900	0·020
1000	0·078
1100	0·24
1200	0·64
1300	1·63
1400	3·35
1500	6·7
1600	12·9
1700	22·4
1800	39·0
1900	60·0
2000	93·0

These numbers have been calculated by the formula of interpolation, where

$$10^{6.7} \theta - \frac{3210}{\theta} = I.$$

the intensity required, in which θ is the temperature absolute ($\theta + 273$).

We can, after having determined the degree of opening of the shutter diaphragm aperture n^1 (by which we establish an equality of intensity between the beam of light projected from the incandescent object sighted, and that of the light of the lamp of comparison, and the absorptive co-efficient K of the tinted glass, if used), draw up a table that gives directly the temperature corresponding to each adjustment of the shutter diaphragm aperture to obtain equality of luminosity.

With a pyrometric instrument for which

$$n^1 = 5.2 \text{ and } K = \frac{1}{25},$$

the following figures are obtained, in which the sign + designates that the tinted glasses were placed before the objective lens, and

the sign — the glasses were placed before the light of the lamp of comparison :—

Temperatures, Degree Cent.	Degree of opening of Diaphragm Aperture.			
	— 1 glass.	0 glass.	+ 1 glass	+ 2 glasses.
700	39·5	...	...	...
800	15·2	...	...	...
900	7·4	...	...	...
1000	3·8	19·2	...	...
1100	...	10·8	...	...
1200	...	6·7	...	...
1300	...	4·2	21·2	...
1400	...	2·7	13·8	...
1500	...	...	10·1	...
1600	...	...	7·4	...
1700	...	...	5·6	...
1800	...	...	4·3	21·5
1900	...	...	...	17·0
2000	...	...	...	13·8

N.B.—In determining the temperature of platinum, magnesia, and lime, the low emissive power of these agents involves the preparation of special graduations.

The following very valuable determinations have been effected—principally with the new optical pyrometer—by M. H. Le Chatelier. The temperature factors are in degrees Centigrade.

Bessemer Process.—Small Converter (Roberts type).

Period of Blow.
1330°

End of Blow.
1580°

Six-Ton Converter.

A.
Bath of Slag.
1580°

B.
Metal in Ladle.
1640°

C.
Metal in Ingot Mould.
1580°

D.
Ingot in Reheating Furnace.
1200°

E.
Ingot under the Hammer.
1080°

Open-Hearth Furnace (Siemens).

Semi-Mild Steel.

A.
Fuel Gas near Gas Generator.
720°

B.
Fuel Gas entering into bottom of
Recuperator Chamber.
400°

C.
Fuel Gas issuing from Recuperator
Chamber.
1200°

Air issuing from Recuperator
Chamber.
1000°

" Chimney Gases.

Furnace in Perfect Condition.

300°

Open-Hearth Furnace.'

End of the Melting of Pig Charge.

1420°

Completion of Conversion.

1500°

Molten Steel.

In the Lander.

Commencement of Casting.

1580°

End of Casting.

1490°

In the Moulds.

1520°

For very mild (soft) steel the temperatures are higher by 50° C.

The bath of steel in the central part of furnace is of a higher temperature than towards the ports.

Siemens Crucible or Pot Furnace.

1600°

Rotary Puddling Furnace.

Furnace.

1340°-1230°

Puddled Ball.

End of Operation.

1330°

*Blast Furnace (Grey-Bessemer Pig).*Molten Metal.Opening in Face of
Tuyere.

1930°

Commencement of
Fusion.

1400°

End, or prior to
Tapping.

1570°

Hoffman Red Brick Kiln.

Burning Temperature.

1100°

RTHEI



r vessel.

DISCUSSION.

Mr. B. H. THWAITE said that M. Mahler had kindly attended to exhibit the instrument. That gentleman, he said, had converted one of the most beautiful instruments of precision into an instrument for an ordinary calorimeter. Since the instrument was introduced in February of the present year, there had been twenty establishments of all classes—iron and steel works and other industrial works—that had taken up the instrument. The method of its use would be explained by Mr. Legros, who had kindly assisted in arranging the apparatus. Mr. Bryan Donkin had also rendered some valuable assistance, and Professor Roberts-Austen had also sent one of his assistants to show the action of the pyrometer.

The following communication was read from M. SCHEURER-KESTNER:—

It is more than twenty years since, either in collaboration with my friend M. Meunier-Dolfus, or alone, I demonstrated the impossibility of determining by calculation, based upon the composition of the coal, its calorific effect, or the heat given out by its combustion. I thought these proofs more than sufficient, and that no one would have any idea of resuming that old theory as to a calculation based on the elementary composition of any substance whatsoever. But I see that I was mistaken, and I have determined to put an end to these doubts once for all, being no longer content with my own experiments merely, but appealing to another experimenter, capable of verifying the results which I obtained, in determining the heat given out by the combustion of two classes of fuel, both very different, but in an opposite direction, from the result arrived at by calculation according to Dulong's law.

In the first place, I desire to remark that I have published "Determinations" of the heat given out by the combustion of coal made in the "bombe" of M. Berthelot, in the month of January 1891.* My first experiments, in the laboratory of the College of France, with the "bombe" date from the year 1888. These experi-

* See *Comptes Rendus de l'Académie des Sciences*, Janvier, p. 233.

ments led me to announce that the results which I obtained, with or without the co-operation of M. Meunier-Dolfus, with the Favre and Silbermann calorimeter, were generally too high, but that "the proportions between the different coals tested calorimetrically remain the same, and my opinion was confirmed that no calculation is capable of giving results worthy of confidence." Before beginning the experimental portion, let us throw a glance on the indications afforded by theory, and we shall see, even before experiment has pronounced, that to pretend to determine, by formulæ such as those well known, the calorific effect of a given coal, or more exactly that of the carbon and the hydrogen contained in that coal, is an impossibility. During the twenty years and more that I have been engaged on these questions, I have always insisted upon the error, frequently committed by engineers, of not taking into consideration the composition, not elementary, but immediate, of the coal. Let us take one example. Let us suppose two specimens of coal having the same elementary composition, and both of them containing 90 per cent. of carbon—it is understood that I mean pure coal, with ash and humidity deducted. One of these two coals leaves by calcination 80 per cent. of its carbon in the state of coke, while the other only leaves 70 per cent. It is evident that the two coals differ essentially through the grouping of the molecules which compose them, seeing that one yields by calcination hydrocarbons much richer in carbon than the other. The carbon in these two specimens of coal will be thus distributed:—

	I.	II.
Fixed carbon	80	70
Free carbon	20	30
	100	100

And yet the same co-efficient for the carbon is used in both cases, which is inadmissible, as we well know, in the light of modern researches in thermo-chemistry. The experiment has only in fact confirmed the rule. Calorimetrical determinations of coal made up to the present time, by Herr Bunte in Germany, by Herr Schwachhoeffler in Austria, and by Herr Fischer, and by M. Alexejeff in Russia, have demonstrated what theory could foretell,

and what old experiments had established, as to the value of formulæ.

Another remark is also necessary from a general point of view, viz., that the partisans and opponents of formulæ do not start from the same basis. The partisans are obliged to demonstrate that the great majority of cases come within the scope of their formulæ, while the opponents are only obliged to show that there are cases in which the formulæ are sufficiently erroneous to cause their rejection. Now, this last proof seems to me sufficiently well established to cause astonishment on my part at seeing the theory of formulæ revived. In a recent paper (*Polytechnisches Journal*, 1891) Herr Bunte has, in fact, revived this theory; and I have thought well this time to take such measures as shall put an end to all controversy on the subject. I have chosen two specimens of coal obtained from the French northern basin, one of which possesses slight calorific power, while the other, on the contrary, is a rich coal. When one finds two coals so dissimilar as regards their calorific effect, and also as far removed in different directions from Dulong's law, the question ought to be set at rest for any one who has a just idea of what is meant by the word "proof." The coals from the northern basin of which I speak are from the Bascoup Collieries "a poor and slightly calorific coal," and from Douvrin Collieries "a bituminous and calorific coal."

Bascoup Coal.—The analysis was made at the laboratory of the Lille Faculty two or three years ago; I have just made it over again, and I have arrived at the same figures. There is, therefore, no possible doubt with regard to the analysis. The heat given out by combustion was determined by myself in the "bombe" of Messrs. Berthelot at the College of France two years ago. I have just repeated the operation, while I begged M. Mahler to kindly burn the coal in the calorimeter of the same type modified by him, in so far as he has replaced the internal platinum by enamel. There is, therefore, no possible doubt with regard to the heat of combustion, since two operators have arrived at the same result. The following are the figures obtained by these two analyses:—

	Lille.	S.K.
Carbon	92.08	92.00
Hydrogen	6.04	5.85
Nitrogen, oxygen, &c.	1.88	2.15
	100.00	100.00

Calorimeter-Bombe.

M. Mahler	8,813 calories per kilogramme.
M. Scheurer-Kestner . .	8,828 " "

Calculation by Dulong's formulæ, reckoning as oxygen all the difference of 1·88 per cent., gives 9,368. Difference between calculation and analysis:—

M. Mahler	555 calories, or 5·9 per cent. less.
M. Scheurer-Kestner . .	540 " " "

This is a result thoroughly determined and incontestible. Here is a coal, the heat given out by the combustion of which is very nearly 6 per cent. less than that shown by Dulong's calculation. In presence of the immense number of the varieties of coal that we know of, and of the very small number of those which have been submitted to the calorimetric test, it may reasonably be asked if there be not a large number of coals similar to or even still lower than that which we have just studied. As to coals which show a greater result than that by Dulong's calculation, even those who are partisans of this formula, like Herr Bunte, have met with some which exceed the calculation by several hundredths. As regards the Ruhr coal (No. 34 of Herr Bunte's investigations at Munich), Herr Bunte has found 9,369 calories. It is by error that he shows less in the final calculation; and a proportion of ash other than that which he admits must be taken into account.* Now, calculation by the Dulong law gives 8,776. Herr Bunte has, therefore, found 593 calories, or 6·6 in excess. Now, 5·9 per cent. less on the one hand, and 6·6 in excess found unmistakably by a partisan of the law, constitute a possible error in the comparison of two coals of 5·9 per cent. + 6·6 per cent. = 12·5 per cent. I am far from asserting that such differences are frequent. I do not know, for the test of coals is much too restricted; but what I say is that in the presence of such results it must be admitted that theory is right in forbidding one to expect calorimetric correctness by calculation. There is here only the question of Dulong's law, the only one of which mention is made, for I do not pretend to assert that future researches will not

* See a note correcting the communication of Herr Bunte, in the *Bulletin* of the Société Industrielle de Mulhouse.

succeed in finding a formula, although that is little likely, because coal is a product of decomposition more or less advanced, and its heat of original formation is modified insensibly, but permanently, by the action of time. It may, therefore, almost be said that one is in the presence of an undetermined substance.

Douvrin Coal.—The second coal of the French northern basin is that of Douvrin. It was, like the preceding, analysed at the laboratory of the Lille Faculty. I determined the calorimetric value on several occasions in the "bombe" of the Collège de France, and the results are concordant. This coal gives the following results:—

Carbon	.	.	.	.	.	.	87·55
Hydrogen	.	.	.	.	.	.	3·77
Oxygen, nitrogen	.	.	.	.	.	.	8·68
							100·00

The "bombe" gave 8,441. Calculation according to Dulong showed 8,002. Addition of the heat given off by the combustion of C+H gives 8,374. Here, then, is a coal which gives not only more than by calculation, according to Dulong's law, but also more than the addition of the calculation of C + H without taking the oxygen into account, as required by Dulong's formula. The difference is + 5·5 per cent. over that given by Dulong's law. If I take the results obtained in the works already published on the heat given out by the combustion of various coals, I notice that, in the determinations of Herr Bunte, there is a coal (1883) which gives 6·6 per cent. in excess of that found by calculation. In these same determinations I find one which gives (Friedrichsthal, Nos. 166 and 167) 471 calories, or 5·8 per cent. less than that shown by the calculation. In Herr Bunte's more recent determinations, which comprise fifteen varieties of Saarbrück coal, the most calorific specimen gives an excess over that shown by Dulong's law of + 3·9 per cent., and the least calorific a deficiency of - 4·2 per cent. Error is very possible with differences of $3·9 + 4·2 = 8·1$ per cent. Seventeen other coals gave Bunte a maximum of + 2 per cent., and a minimum of - 3·7 per cent., a difference which may cause an error of 5·7 per cent. Herr Schwachhoeffer has found, in a less considerable number of coals, divergences from Dulong's

calculations of + 6 per cent. and - 2 per cent.—divergences which may cause an error of $6 + 2 = 8$ per cent. Quite recently Herr Mahler, in a communication as to his modification of the Berthelot "bombe," instanced determinations of the heat given out by the combustion of four descriptions of coal and two of anthracite. Herr Mahler's figures come near to those by Dulong's law. Between the two extremes of Commentry and Lens coal there is a difference of + 1.4 and - 1.3 = 2.7; and yet the number of coals is only four! It should be remarked that the Treuil coal gave Herr Mahler a result more nearly approaching simple addition than Dulong's law.

To sum up, it follows from the preceding observations that the heat given out by the combustion of coal is most irregular when compared with its chemical composition; that sometimes this is lower and sometimes higher than that shown by calculation according to Dulong's law; that the differences, more or less, extend in the case of coals (too few of which have hitherto been tested calorimetrically) from - 6 to + 6 per cent.; that there is nothing to show that these differences will not be still further increased by fresh determinations of different specimens; and that in the present state of science it is not possible to find a formula which will permit of arriving by calculation at a knowledge of the calorific value of a given coal. I wish especially to repeat this observation, that the minimum of - 6 per cent. is established, after argument *pro* and *con*, in the case of the Bascoup coal, and that of + 6 per cent. has been attained by several authors. No one can therefore have a shadow of a doubt on this point. As regards the concordance of calorimetric determinations, I might further instance that of Nixon's coal. Herr Mahler has been good enough to inform me of the figure which he arrived at, and which reaches 8,759 calories. I found quite recently (in April) with the Berthelot "bombe" 8,701 calories. I abstain from considerations as to a comparison between the heat of combustion of this coal and its composition, because I notice in the communication of Mr. B. H. Thwaite that we do not agree as to this composition. As regards this communication and the figures there quoted concerning the former experiments made in collaboration with M. Meunier-Dolfus—and not with M. Walther-Meunier, as Mr.

Thwaite says—I would observe that the figures of the calories are too high by several hundredths, as I announced more than a year ago. In any case, however, their relative values are correct, the same mistakes with the Favre and Silbermann calorimeter having naturally always led to the same results.

The following communication was read from M. LE CHATELIER :—

The researches of M. Mahler that Mr. Thwaite has been good enough to present at the Congress of the Iron and Steel Institute have been carried out under the auspices of the Society for the Encouragement of National Industry in France. The Society, founded in 1801, has, by the results shown at the Congress, the prizes it distributes and the bulletin that it publishes, rendered signal service to industry at a time when technical instruction was not diffused as it now is, and when industrial publicity did not exist. At the present time, considering the striking, and daily more marked evolution of industry towards the exclusive use of scientific methods of work, several members of the Société d'Encouragement have been considering whether this society, to preserve its old influence and to raise resources which it disposes in an exceedingly useful manner, should not in its turn modify its line of action. Industrial proceedings, which for many centuries have remained entirely empirical, now tend to be replaced by processes based upon a precise knowledge of natural phenomena and the laws which govern them. The exact measurement of the different pyrometers which define the physical properties of bodies (dilatation, specific heat, tenacity, &c.) can themselves furnish at the present time a sure basis for industrial progress. But researches of this description are very difficult to prosecute in factories amongst the perpetual agitation caused by the struggle for existence. Does it not rather belong to industrial institutes to carry on in scientific laboratories researches of this nature, in order that they may afterwards hand over their utilisation and active working to men of action at the head of factories?

The Société d'Encouragement has been preceded in this path of research by different industrial societies. I should particularly mention the Institution of Mechanical Engineers and its Com-

mittee of Research on Alloys, to which bodies we owe most interesting work.

It is with these views that the Société d'Encouragement deputed M. Mahler to make a complete study of the calorific power of industrial fuel. The knowledge possessed up to now with respect to this important subject is very imperfect, by reason of the imperfection of the experimental methods employed. The calorimetric machinery by which combustion is obtained by a current of oxygen under atmospheric pressure is exposed to two possibilities of very grave error. There is always a remainder of hydrogen and of carbonic oxide not consumed, and often also coal-tar and coke. Further, the gases consumed never escape at the exact temperature of the calorimeter, and bring with them a variable quantity of steam. With scientific appliances which, by somewhat complicated processes, permit of the rectification to a certain extent of these two causes of error, one may hope for exact measurement within about 5 per cent. ; but with the industrial apparatus, which do not provide for correction, it does not seem possible to answer for the correctness of the results within 10 per cent. This does not prevent, as will be understood, the obtaining with a given instrument results which agree remarkably well. For this it is only necessary to always work under identical conditions, in which case the errors would be always the same ; but to conclude that the errors do not exist because they are always the same would be to deceive one's self strangely.

The admirable calorimetric method due to MM. Berthelot and Vieille, by which combustion is produced in a closed vessel surrounded by compressed oxygen, eliminates, on the contrary, entirely and absolutely the two causes of error which have been pointed out, and permits us to determine the calorific power with an uncertainty of less than 1 per cent. It is by this method that M. Mahler's experiments have been performed, those which have been communicated to you by Mr. Thwaite, as well as the much larger number which are in course of publication in the journal of the Société d'Encouragement. The results thus obtained, compared with those which had formerly been obtained by less precise methods, enable us to appreciate the amount of confidence merited by these last methods. But M. Mahler is not content with having

employed the calorimetric bomb of MM. Berthelot and Vieille, he has still further modified it by improvements of considerable practical importance. Out of an apparatus which was an article of luxury possessed by only a small number of scientific laboratories, he has evolved, without altering in the least its great exactitude, a practical apparatus perfectly adapted to the needs of industrial laboratories. He has besides claimed for this apparatus right of property, and has pursued all these researches in a merely scientific purpose.

Mr. THWAITE said that M. Mahler wished to make a statement through him. He did not agree with M. Scheurer-Kestner, but considered that the law of Dulong was satisfactory for ordinary industrial purposes. M. Mahler agreed with M. Bunte. He believed that the difference between the law of Dulong and the calorific power observed was considerably less than as stated by M. Scheurer-Kestner. He thought it absolutely necessary that the analysis should be quite perfect. He made that statement after a considerable number of experiments, exceeding one hundred, both analytical and calorimetical.

M. MAHLER then exhibited the instrument, and by means of an experimental test explained its mode of action.

The PRESIDENT said the Institute was much obliged to M. Mahler for his kindness in showing the operation of the calorimeter. He had the pleasure of seeing the original calorimeter in use some years ago at M. Berthelot's laboratory. Having had something to do with calorimeters in determining the heat of explosives, he could not speak too highly of the work done by the particular apparatus just exhibited. The thanks of the members were due to M. Mahler and Mr. Thwaite for the way in which the apparatus had been arranged and explained.

Mr. LEGROS desired to say a few words on the Thompson calorimeter. Mr. Thwaite, he thought, had not been quite fair to that calorimeter, because he was comparing the form shown on the 1892.—i.

P

table with M. Mahler's instrument, which had been a good deal worked up. Since the Thompson's calorimeter had been made, it had been the subject of a good deal of improvement. The old Thompson calorimeter had a tin outside jacket, which was now replaced by a glass shield, so that the whole operation inside could be seen. The diving-bell was made with a different joint at the bottom, and underneath, instead of trusting to the gauze to break up the screen, there was a pipe terminating in nozzles, so that the gas was obliged to escape in very small bubbles, and was more perfectly in contact with the liquid.

With regard to the work done by the two calorimeters he had, through the kindness of the Scotch Smoke Prevention Committee, obtained a sample from Wilson's Dross Douglas Park Colliery, Lanarkshire, which was used at some of the Scotch Smoke Prevention trials. The analysis of the coal gave: carbon, 54.48 per cent.; hydrogen, 4.49; ash, 16.54; water, 7.84; hygroscopic water, 5.20. A portion of the coal was sent to M. Mahler, who tested it in his apparatus, and obtained a value of 6020 calories, equal to 10,845 thermal units.

Independently of that, he made determination with the instrument, taking a weight of $2\frac{1}{2}$ grammes of coal. Two thousand grammes of water were put inside the vessel, the total equivalent of the apparatus being 2116 grammes, and the rise was less than 1 per cent. The result of the observation gave 10,880 thermal units as against 10,840. He mentioned that to show that very similar results might be obtained by that instrument and M. Mahler's. There was one point in connection with all calorimeters of that type, in which the water present in the coal, and formed during combustion, was condensed inside the apparatus. In ordinary practice the water escaped into the atmosphere in the form of vapour, and the latent heat was lost to the manufacturer. In the case of the bad coal, with 4.49 per cent. of hydrogen, the water would amount to 40 per cent. of the weight of the coal, and the heat so lost would amount to 4 per cent. of the total heat of the combustion of the coal. He would ask whether it was worth while to consider such great niceties when there were such big errors between the determination as made in that way and in ordinary work.

Mr. BRYAN DONKIN said that Mr. Thwaite did not say who the equivalents were by, whether by M. Mahler or Mr. Thwaite.

Mr. THWAITE said he would remedy that.

Mr. H. C. JENKINS said he wished to make a few remarks with regard to the pyrometer and the calorimeter. Mr. Thwaite was rather hard upon the thermo-couple. It was not intended to be put into the hands of workmen, but certainly in an office or laboratory it ought to be quite safe. On page 15 the author rather urged that no pyrometer should be in contact with the furnace or put into the furnace for temperatures above the melting point of platinum. It was manifest that they could not expose the apparatus to the temperature of the furnace, but up to that, where the part exposed was simply as it was in the thermo-couple, merely two pieces of metal, the sweeping remark which had been made hardly seemed to hold.

In his experience of the thermo-couple in Professor Austen's laboratory, he found that although after long exposure to carburising influences the wires did get demoralised and broken, no errors were introduced into the reading, and when a fracture did occur, the wires merely had to be twisted together beyond the damaged point. He was speaking of the temperatures of about 1400° centigrade. In the instrument of Nouel and Mesuré, the author said the results were only widely approximative. They found them widely approximative too, but Mr. Thwaite did not point out the reason very clearly why they were so widely approximative. The reason was they had to measure the exact tint to which the instrument had been calibrated. If makers of those pyrometers would only supply them with some standard eye-piece he thought the very simple instrument of Nouel would be much more useful.

Then, on page 17 a very important point was referred to, namely, that the intensity of radiation depended not only upon temperature but upon the particular nature of the body and its surface, the emission effected in two very different bodies only varying one ten-thousandth part. The tests that he had assisted in making made it about one two-hundredth part, say 13° centi-

grade, which was much larger than a ten-thousandth part. Of course in a furnace they hardly ever saw iron; they saw iron oxide, which covered the surface. The iron behind the scale was not seen at all; it had become quite opaque. The difference between iron oxide and brick was about a two-hundredth part. He had only given them the figures very roughly.

With regard to the adjustment of the instrument, he was afraid from what he had seen of the instruments it would have to be left to the makers. The instrument which Professor Austen had sent down was a small mass of iron covered of course with oxide. If placed over a thermo-couple, by means of a galvanometer and scale, the temperature of that piece of iron could be read off. It could be viewed through one of those new instruments and the temperature taken. But the readings of the photometer must of course be plotted down to the known temperatures indicated by the thermojunction.

Mr. B. H. THWAITE, in replying to M. Scheurer-Kestner's valuable contribution to the discussion, desires to say, that whilst admitting the inapplicability of Dulong's law for the calculation of the thermic value of fuels constituted of hydrocarbons of a complex character, he is nevertheless in accord with M. Pierre Mahler in considering that for ordinary coals, Dulong's law may be applied with a result that will be sufficiently near for most industrial purposes. It is, however, obviously essential that the analysis shall be rigidly accurate, and that, instead of Favre and Silbermann's coefficient for carbon being taken, the latest determination of M. Berthelot should be employed. This gives—

Heat of combustion of carbon = 8140.

M. Scheurer-Kestner refers to a comparative test with Baseoup coal; the analytic constitution, according to M. Scheurer-Kestner, was—

C = 92.00 per cent.

H = 5.85 „

O = 2.15 „

The calorimetric determination made by M. Scheurer-Kestner

= 8·825 cal. per kilo. According to the analysis of this same coal made at the École Nationale des Mines, the constitution is—

C = 92·19 per cent., a difference of 0·19 per cent.					
H =	4·24	"	"	"	1·61
O and N =	3·57	"	"	"	1·42

So that the difference in the degree of care with which the analyses are performed may explain the discrepancy between the calculated and calorimetric result. According to M. Deutcom, the law of Dulong gives results that only vary from the calorimetric ones by a figure not exceeding 3 per cent., and in the majority of instances the results only vary by 1 per cent.

M. Deutcom's calorimetric investigations were conducted on a comparatively large scale; instead of a few grammes of combustible he has used hundredweights. The variation of 1 per cent. would be partially explained by between Favre and Silbermann's co-efficient for carbon and that of Berthelot's:—

$$\begin{array}{l} \text{Favre \& Silbermann's} = 8080 \\ \text{Berthelot's} \quad \dots \quad = 8140 \end{array} \left. \vphantom{\begin{array}{l} \text{Favre \& Silbermann's} \\ \text{Berthelot's} \end{array}} \right\} (8080 - 8140) = 60$$

Dulong's law corrected should read thus:—

Where

C = Carbon.

H = Hydrogen.

W = Latent heat of water vaporisation at the temperature of the air, to steam at 100° C.

O = Oxygen being taken as existing in combination with the H. of the water.

S = Sulphur.

Then

$$8140 C + 29,300 \left[H - \frac{O}{8} \right] + 2,240 S - 600 W. = \text{heat of combustion in calories.}$$

A further correction is required for fuels containing a relatively high percentage of sulphur; this element may be the cause of a possible disagreement between the value calculated by Dulong's law and the observed calorimetric one.

The elements sulphur and carbon, when burnt or oxidised separately, evolve when associated as carbon bisulphide (CS₂) per unit of weight as follows:—

Proportion of Weight.	Calories.
C = 0·1579 per cent.	= 1275·8
S = 0·8421 ,,	= 1887·2
1·000	3163·0

Whereas the oxidation of one unit of CS_2 equals 3,792 calories.

The difference in the value is nearly 16 per cent. It is thus necessary, when Dulong's law is applied to coals containing sulphur, that a correction equivalent to the ratio set forth should be made.

Dr. Bunte, than whom no one has given greater attention to the subject under consideration, is in accord with the author and M. Mahler, that the law of Dulong is sufficiently accurate for industrial purposes. The objection to the general use of the law is the difficulty in obtaining precise analytic results, the laboratory *operandi* being very delicate, whereas the calorimetric determination with the Berthelot-Mahler and with the Thomson instrument, is much more convenient and simple, and carries in its train few sources of error.

Replying to M. Le Gros, the author considers that M. Le Gros cannot have known that he (the author) has had the honour of assisting in the popularisation of the Thomson instrument, which, despite its inferiority to the Berthelot-Mahler type, he considers to be worthy of a place in most industrial laboratories. Nevertheless for precise determination the Berthelot-Mahler is the most suitable of the two instruments.

Referring to the calorimetric results obtained by M. Le Gros with the Thomson instrument, and their nearness to the determinations with the Berthelot-Mahler calorimeter—the same class of coal being used—Mr. Thwaite regards this as satisfactory, but he considers it more due to hazard than to the closeness of efficiency of the two instruments. From information received by the author from M. Mahler, he considers that the fuel, in its chemical constitution, can hardly have been of the precisely identical character claimed by M. Le Gros.

According to M. Le Gros, the proportion of ash in the sample of coal tested by him was 16·54 per cent. In the sample of coal tested by M. P. Mahler the proportion of ash was 18·80 per cent.
Verb. sap.

To fairly compare the results of the two tests, M. Le Gros should have commenced by abstracting the losses due to the proportion of ash and hygroscopic moisture, which vary even with coal from the same pit.

The author admits the loss in the absorption of heat rendered latent, due to the oxidation of the H to H_2O , but this does not reduce the importance of extreme accuracy in the calorimetric results. M. Le Gros's reference, however, is useful as a confirmation of the objections the author raised some time ago as being associated with the use of water-gas, in which the proportion of hydrogen carries with it in its oxidation to H_2O a loss due to the proportion of heat rendered latent.

This heat can, however, be recovered by subjecting the products of combustion to a condensing influence which shall be of such a character as to reduce the temperature of the H_2O below $100^\circ C$.

The author trusts that future methods of utilising hydrogen as a combustible agent will be accompanied with methods of condensation that shall obviate the losses mentioned.

The author, replying to Mr. Jenkins, wishes to say that he did not intend to detract from the value of the thermo-electric couple; he simply desired to show that this pyrometric instrument, beautiful as it is, does not possess those characteristics that are required to enable it to be used in every-day industrial work.

He quite agrees with Mr. Jenkins' references to the Nouel & Mesuré instrument, than which there could hardly be a neater adaptation of the optical principle for high temperature measurement.

There is, no doubt, a greater difference between the emissive powers of different bodies than that given by M. H. Le Chatelier, but once the emissive powers are accurately defined, correction for this action can be easily made. The author quite agrees with Mr. Jenkins in that the adjustment should be left to the makers of the optical instrument.

The author wishes here to thankfully acknowledge the kind and valuable assistance he has received from M. Pierre Mahler, who has attended the meeting from Paris to assist in the practical demonstration of his instrument; from M. H. Le Chatelier and M. Pellin for the loan of the optical pyrometer; from M. Golaz,

for the very beautiful work of which the Berthelot-Mahler instrument is an example; from Professor Roberts-Austen, C.B., for his assistance in demonstrating the *operandi* of measurement of high temperatures with the Chatelier thermo couple; from Mr. Bryan Donkin, jun., M. Le Gros, and Mr. Jenkins, for assistance in arranging the apparatus; from the Brins Oxygen Company, Limited, for arranging the oxygen apparatus; and from Messrs. Oertling, for the very perfect analytic balance.

A PRACTICAL SLIDE-RULE FOR USE IN THE CALCULATION OF FURNACE CHARGES.

By ARTHUR WINGHAM.

THE calculations necessary for the preparation and control of furnace charges and material are often long and tedious, and, moreover, frequently require a ready knowledge of chemical formulæ or equations and atomic weights. It is well understood and recognised in works that any means which will shorten the time and trouble bestowed upon such calculations should be encouraged and valued as so much gained. The present slide-rule has been constructed for the purpose of giving immediate and, at the same time, accurate results. It can be applied to and utilised in various manufactories, but it will probably be found to be most useful in iron and steel works.

There are already some well-known methods of ascertaining from analyses the acidity or basicity of slags or ore gangues, and the amounts of fluxing materials required for the same, amongst which may be mentioned Balling's tables, and a method described at the last Spring meeting of this Institute by Mr. Jenkins.*

All these methods, however, require a certain amount of manipulation and calculation, which may be looked upon as loopholes for error, and which can now be avoided.

The principle on which the slide-rule is constructed is that of having a scale for each base, basic material and acid, so divided that any given length or quantity of one will show in the same length of the other the quantity of material which will be necessary either to displace or combine with it as the case may be. These scales are placed side by side in such a position on the rule that the rectangular end of the slide above them measures the amounts of each material which chemically correspond one to the other. Thus, for instance, when the slide is withdrawn

* *Journal of the Iron and Steel Institute*, vol. i., 1891, p. 157.

to the figure 20 on the lime scale, it indicates the amount of each of the other bases which chemically and metallurgically possess the same basic power of displacement, viz., magnesia 14·3, alumina 12·3, soda 22·1, &c. Furthermore, it shows the amounts of silica which are necessary to produce a monosilicate (neutral), a sesquisilicate, and a bisilicate slag.

The practical use of the scales is further enhanced by the peculiar construction of the rule. It consists of a framework or body about 12 inches long, $1\frac{1}{4}$ inch wide, and $\frac{1}{4}$ inch deep, into a broad shallow cutting near the surface of which slides to within an inch of one end a long rectangular slip of wood, which may be designated the *main slide*. In the body underneath this main slide are four narrow slides, which are moved by prominences which reach beyond the surface of the main slide at one end. These under-slides can only be moved when the main slide is out, and the closing of the latter shuts up all the former. On each of these four under-slides is marked one of the following basic scales :—Magnesia, alumina, soda, and ferrous oxide (manganous oxide is practically the same as ferrous oxide). The lime scale is marked upon the lower surface of the body close to the silica scale.

As an illustration of the way to use the slide-rule, we will suppose that it is necessary to find out to what extent the bases or acid predominate one over the other in the gangue of the following ore, and to ascertain the quality and quantity of fluxing material required to neutralise the excess, so as to produce a monosilicate slag. The ore has the following percentage composition :—

	Per Cent.
Iron	40·5
Lime	6·5
Magnesia	4·2
Alumina	10·4
Silica	18·2

The main slide is first withdrawn until the figure 6·5 on the lime scale (the percentage of lime) is just disclosed, after which the under-slide MgO is pushed out up to the end of the main slide. (Fig. 1 illustrates the rule in this position.)*

* Showing the percentage of lime read off by the main slide, and the under-slide MgO pushed up into position ready for reading.

The main slide is now withdrawn until the figure 4·2 on the MgO scale is reached, and the alumina slide is then brought into position. A further withdrawal of the main slide until the figure 10·4 on the Al_2O_3 scale is reached records at once the amount of silica, 15·7, which will be neutralised by the three gangue bases present. (Fig. 2 illustrates the rule in this position.)*

The amount of silica in excess is therefore $18·2 - 15·7 = 2·5$, so that closing the slides, and referring once more to the lime and silica scales, it will be seen that for this excess of silica it is necessary to add 4·7 parts of lime to form with the gangue a monosilicate slag. Therefore 100 parts or tons of the ore would require as a flux for its gangue 4·7 parts or tons of lime.

If a sesquisilicate slag is required, then the operation is identical with the foregoing, except that the sesquisilicate scale is read off instead of the monosilicate. Similarly a bisilicate slag can be arranged for. Then, again, from the analysis of a slag it is only a matter of a few moments to ascertain to which class it belongs, and, in the case of its being again used in the furnace, to register its acidity or basicity.

In this slide-rule it will be seen that under-slides have been provided for the principal bases of slags, and that the silica has been arranged into scales corresponding to neutral and acid slags. No scale of the silica for a basic slag has been made, because there are so few basic operations in which any quantity of silica is definitely aimed at, the rule generally being to keep the slag as basic as possible.

On the reverse or inside of the main slide is given a number of scales corresponding to the following bases and fluxing materials:—Sulphur, lime, limestone, soda, potash, ferrous oxide, ferric oxide, lead oxide, cuprous oxide, zinc oxide, and silica for a monosilicate or neutral slag. From these it can be seen at once that the quantity of limestone equivalent to the above 4·7 tons of lime to be added to 100 tons of ore is 8·4 tons. If the limestone is siliceous at all, its basic value can also readily be ascertained by deducting the amount which will be used by the

* Showing the position of the MgO and Al_2O_3 scales after having been read off, and the position of the main slide indicating the quantity of SiO_2 required by the three bases.

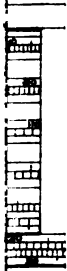
quantity of silica it contains, and due allowance can then be made in its application. The amount of limestone which is necessary to form sulphide of calcium with the sulphur in the fuel used can similarly be ascertained. If it is required to use one of these bases in connection with those on the under-slides, it is only necessary to read off the corresponding amount to such base on the soda scale, and then use the soda under-slide to the figure so obtained.

In the case of low percentages, whenever possible, it will be found advantageous in respect to giving a closer result to temporarily utilise the tens on the scales as units, and the units as tenths of one unit. The theoretical percentage composition of a slag with one base can also readily be determined by withdrawing the main slide until the figures on the acid and basic scales added together equal 100. The other scales on the reverse will be found to be of use in many kinds of operations involving displacement of one base by another, whether by chemical or metallurgical means. Among these may be mentioned the amounts of ferrous and ferric oxides necessary to displace any cuprous oxide in a slag; the quantity of lime which will displace any percentage of lead oxide, oxides of iron, &c.; the amount of sulphur required to form a regulus with ferrous and cuprous oxides, and so on.

The main principle of this slide-rule, viz., having different scales so divided that equivalents of various bodies may be measured by the same length, can be utilised, probably with a great amount of advantage, for many technical purposes by the creation of special scales. In the present instance it has been arranged for application to cases involving metallurgical operations, and to such an extent that the amounts of the base required to form a neutral slag with any quantity of silica up to 100 parts are given.

There are many other forms which the slide-rule could take, some perhaps of at first sight a less complicated construction; but the present one is preferable for various reasons, foremost amongst which is the fact that the scales are inside, and well protected from dirt or obliteration by rubbing; consequently the instrument can be carried about without spoiling, and can be always at hand.

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Among the chief recommendations of the rule is the fact that it contains a large amount of information in a very small space, and in a form by which are given results sufficiently accurate for practical purposes. These results can be obtained in a very short space of time without the probability of that inaccuracy which is so often attendant upon rapidly-made calculations. The slide-rule can be easily worked, and does not require a scientific knowledge on the part of the person using it. At the same time it is not put forward with the view of encouraging incapacity, but more to save the time of those who could do without it, and to aid the practical operator in the growing necessity of paying closer attention to scientific laws. It will be found useful in all works employing metallurgical processes involving the employment and production of slags, in glass-works, in slag-cement and other manufactories concerned in the economic application of slags.*

I am much indebted to my friend Mr. H. G. Graves for his assistance in enabling me to prepare the models and for the drawings to this paper. The manufacture of the slide-rule has been entrusted to Messrs. John Davis & Son of Newgate Street, who have succeeded in making some very neat instruments, a few of which have been brought to the meeting for inspection.

The PRESIDENT said the members were much indebted to Mr Wingham for his paper on what appeared to be a very useful instrument.

* *Jour. Soc. Arts*, vol. xxxviii., 1890, p. 221, Paper by G. Redgrave.

ON VALVES FOR GAS FURNACES.

BY J. W. WAILES.

THE importance of thoroughly efficient valves for furnaces using gaseous fuel is sufficiently well known by the large body of users of this class of furnace to need no more from me than a passing remark. If we consider the large amount of coal that is applied to manufacturing purposes at the present day in the form of gas, it requires little insistence to enforce the important fact that even a small escape that finds its way to the chimney without passing through the furnace or doing any work represents in the yearly aggregate a very formidable sum to be put down under the head of absolute loss. The escape is, however, often anything but small, and is always constant when valves are leaky.

That there is a weakness in furnaces in the detail of valves is well known and generally recognised, and it is attested by the fact that over eighty patents have been obtained for improvements in valves and connections therewith.

Regarding the functions of these valves, the first consideration that strikes us is that the currents to be controlled and directed are of very small pressure, not equal to more than about half to three-quarters of an inch of water. If it were only a question of dealing with the incoming gas and air at their moderate temperatures, the problem might not offer any great difficulty, but the question is at once complicated when the outflowing currents from the furnace have to be considered, as these currents, from a variety of causes, are often at a high heat—sufficiently high to destroy the fit of the valves. It may be urged that these conditions should not be allowed to arise; but they do arise, and it is often the task of the engineer to deal with things as he finds them, when unable to obtain what ought to be.

Another condition that always exists is furnished by the fact that the pressure of gas acts on one side of the valve, and the draught of the chimney on the other, so that inaccuracy in the

fit of the valve allows very serious loss. And here a further complication comes in; the escaping gas ignites at the under side of the valve, and the heat resulting continually makes the trouble worse. I have often noted with surprise, on examining a valve removed for repair or refitting, how a comparatively small defect had impaired the working of a furnace; and as a leakage has the effect of delaying the operation of a furnace, the defect acts and reacts—the greater the defect the greater the delay, and the greater the delay the greater becomes the defect.

A large number of furnaces at the present time are working with the original four-way type of flap-valve. This valve is too well known to require description here. In the presence of engineers it is hardly necessary to state that whatever advantages this form of valve may have, when it is once out of shape it is a matter of impossibility to make the flap fit again. If you are successful in obtaining a fit on one side, it is at the cost of a misfit on the other; so that the plan that usually obtains is to arrive at a kind of a compromise by making the best fit possible under the circumstances at each position of the flap, but not good in either case.

Another form of valve that has been largely adopted lately is that of the double-seat type, with a circular valve on a spindle alternately closing on one or other of the seats. This form of valve being of massive construction and uniform shape, is not so greatly affected by heat, and gives, I think, better results than the old four-way type just referred to; but it is open to many of the objections common to all classes of cast iron gas valves. If we consider the small pressure furnace valves have to resist, the idea of employing these heavy masses of cast iron becomes something very like a mechanical absurdity.

In the valve to which I have now to direct your attention it has been attempted to obtain an absolutely gas-tight closure—a perfect water-seal—and at the same time to entirely avoid any of the objections to the use of water arising from evaporation filling the flues with vapour, or cooling the current so as to impair the draught of the chimney. In the belief that these conditions have been obtained must be my excuse for occupying your time with a matter so simple; but though simple, it has, I think, a very important bearing on a most gigantic branch of

metallurgical enterprise. I also trust it is an earnest and well-meant attempt to perfect in one of its important details the great invention left by the genius of Siemens.

The valve (if it may be so called) is of the most simple form and construction; it is merely a trap constructed of malleable plate, like an ordinary gas-tube, the passage being closed and opened by being filled and emptied with water. A vessel holding water is raised and lowered on this trap; the vessels being balanced, and friction absent, little effort is needed to perform this operation. When the heated currents are passing, the passage is empty and dry, so that, as I have stated, the important condition of avoiding evaporation and cooling is obtained. There is absolutely nothing to get out of order; if the passages are distorted by heat at any time, no harm is done; the water simply fills the space, of whatever shape it may be. Small leaks, if they should arise, are of little consequence. There are no inside parts; the whole is seen from the outside; in short, it is as simple and free from complications as any part of a gas-tube.

Diagram No. 1 shows the action of the valve. A is the passage, B the vessel of water.

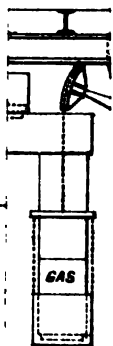
The valve is now open; when the vessel is raised, the water flows through the narrow opening in the bottom of the trap till it reaches the line C, when it is absolutely closed without the most remote possibility of leakage.

The other view shows the vessels attached to the lever and in equilibrium. D is the passage between the gas supply and the furnace, and E the connection between furnace and chimney. The valve is operated by the motion of the lever.

Diagram No. 2 shows an arrangement of valves for a furnace. This appears to meet all the best conditions to be desired. The flues are perfectly straight, and without complication. Of course the valves may be arranged in any way to meet exigencies.

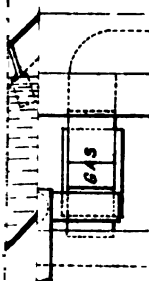
The opening at the bottom of the gas-passage through which the water flows is larger than in the case of the chimney-passage, as heated currents do not pass this, and extra opening is no objection; and by keeping sufficient room at this point the tar falls freely into the water vessel, and is easily removed if it should collect. The operation of reversing must be done by

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steady means, such as a screw, worm-wheel, or means not liable to jerks, which might spill the water. The water vessels, by means of a ball valve, may be automatically supplied, or it may be done by hand with a small hose-pipe.

The arrangement has the further advantage of being inexpensive, durable, and requiring very little in the way of maintenance.

The water-valve need only be used in the case of the gas, the air-valve may be a simple tube with a flap, as a perfect fit in an air-valve is of small consequence.

It only now remains for me to state that in actual operation the valve fully realises my expectation, and, I am assured, leaves very little to be desired with regard to this important furnace detail.

DISCUSSION.

Mr. THWAITE said that this was a subject of importance to all open-hearth steel men. Mr Wailes mentioned the various temperatures to which the valves had been subjected, but had not given the calculation showing the thermic loss due to the valves. In a paper which he had read before the Staffordshire Institute of Managers on the subject of open-hearth steel furnaces, he had shown it was possible, with ordinary valves 18 inches in diameter, with half an inch leakage, they might have a loss equal to 34 per cent. of thermal effects contributed by the gas, simply because the connection with the chimney was more direct. That was the most serious objection to the open-hearth furnace as at present constructed. If there were the slightest leakage, the whole pull of the chimney was thrown on to the leakage, and 34 per cent., due to half an inch of leakage, was something to be considered. There was another point. Every time the reversal was effected he had calculated that the accumulation of gas left in the recuperator gas chamber, per ton of metal on the furnace, gave a loss equal to 22,000 calories. The question for open-hearth furnace men was whether there was any necessity to make direct connection with the valve at all.

Mr. A. FURZE asked if the valve were an expensive one? He should like to ask that question, as it seemed rather complicated on the diagram. In his neighbourhood they had many simple valves in a firebrick form which did the work very simply and very effectively.

Mr. BRYAN DONKIN said he should like to know whether there were many of the valves in operation, and what were their sizes?

Mr. WAILES, in reply, said that he did not think he could go into the question of expense, as it had been laid down that all commercial questions should be avoided. The member who had asked the question, being an engineer, would naturally look at

what was before him, and he had no doubt would be able to form his own opinion as to the cost. The valve was merely a trap. It was nothing more than what they could see in any drain. The object, as he had explained in the paper, was to withdraw the water when the heat passed through the valve. It was necessary to get rid of the water when the heat passed through, for the reason which he had explained—that the evaporation was a very great nuisance in the water-valves. In these water-valves the heat passed over the valve, and did not pass the jacketing. The importance of a perfectly reliable gas-valve that would close without the shadow of a doubt of leakage was, as every manager or owner of gas furnaces knew, a most important thing, and he quite agreed with Mr. Thwaite that an extremely small opening in a gas valve allowed a very serious loss of gas, and was a great detriment to the working of a furnace.

He had never gone into such careful calculations as Mr. Thwaite had made as to the actual loss of heat due to what might escape through a valve, but he knew practically that a valve with a slight misfit would often stop a furnace absolutely from working. In this valve there was a perfect closure, so that they could always be absolutely certain that there was not the slightest chance of waste—in fact, that it was a physical impossibility for any waste to take place. There were now in use about five sets on melting furnaces, and about six or eight sets on heating furnaces, and they were working admirably. The five sets on the melting furnaces were rather large—larger than one would make cast-iron valves, because the cost of making them a few more inches in area was such a very small matter as to be hardly worth considering. These valves, on 30-ton melting furnaces, were 3 feet wide by 2 feet deep, which was a very large area.

The PRESIDENT said he would ask the members to return thanks to Mr. Wailes for his interesting communication. As, with that paper, their business came to a close, it was his duty and pleasure to submit to them a resolution, namely:—

“That the best thanks of the Iron and Steel Institute be accorded to the Council of the Institution of Civil Engineers for the loan of their room for this meeting, and for the general facilities

which they have always, as on the present occasion, so kindly afforded us in connection with our meetings."

The motion was carried by acclamation.

MR. WILLIAM WHITWELL said they had now come to the conclusion of a meeting which had been full of interest. He did not remember a meeting where more information had been given and obtained, or more interest shown by the members, whose attendance up to the close was more satisfactory than it had been at some of their previous gatherings. This was in no small degree owing to their great appreciation, not only of the character of the papers, but of the care taken by the President in putting such interesting papers before them. He felt most fully that their appreciative thanks were due to the gentlemen who had prepared those admirable papers for the time, care, and talent which they had bestowed upon them. But there was another vote of thanks which they must not omit, and he therefore moved—

"That the most cordial thanks of the members be given to Sir Frederick Abel, K.C.B., &c., President of the Institute, for his admirable conduct in the chair."

MR. HADFIELD seconded the motion, which was carried by acclamation.

The PRESIDENT said he was greatly indebted to Mr Whitwell for the very flattering way in which he had placed his (the President's) small merits before the members, and to the latter for having endorsed what had been said regarding his efforts to make the meeting a successful one. He thought they had had a very successful meeting; there had been two or three discussions above the average, in point of interest, of many ordinary meetings, and he trusted that their gathering a few months hence would be as interesting and as instructive to them all as the present one had been.

THE CALORIFIC EFFICIENCY OF THE PUDDLING FURNACE.*

BY MAJOR CUBILLO, TRUBIA, SPAIN.

SINCE empirical methods have been abandoned in the metallurgy of iron and steel, and rational methods, based upon chemistry and physics, have been applied in their place, remarkable progress has been made, and this progress is specially noteworthy in the case of the iron industry.

Of the metallurgical processes employed for the extraction of this metal from its ores, and for its subsequent treatment, those generally employed are furnace methods, processes which always require an elevated temperature, and consequently the production of heat.

The combustion of some of the substances which occur in great abundance in nature offers for industrial purposes an economic means of effecting the production of this heat. At the present time, it may be assumed that only those substances that contain hydrocarbons in one form or another are those upon which the iron industry relies for the evolution of heat. This is due to their physical character, as well as to the considerable amount of energy which they are capable of yielding per unit of weight. In furnaces or other appliances used in igneous metallurgical processes, and intended for the production of heat, the whole of the heat produced is not completely utilised. The case, indeed, is quite analogous to that of the steam-engine, there being always a difference between the heat yielded by the fuel, and that actually utilised in the furnace operation.

This relation between the heat utilised and that available by the combustion of the fuel is what is termed the effective furnace value or efficiency.

The admirable researches of Gruner and of Sir Lowthian Bell on the determination of the calorific efficiency of the blast furnace are well known, and following such distinguished masters the author has attempted to apply the same methods to the puddling furnace.

* Paper taken as read.

The furnace employed in this investigation was of simple construction, with no other peculiarity than that of being equipped with a modified form of Boetius gas-producer; whilst a small furnace for heating the charge prior to placing it on the furnace-hearth was also employed. The gases from the producer entering the furnace receive the air necessary for their combustion through orifices in the fire-bridge and in the roof. The air that enters through ducts in the fire-bridge, passes in from below the bed of the furnace, and that which enters by the roof passes through flues in the sides of the fireplace. In this way the air is heated before entering into combination with the combustible gases, adding to the calories resulting from the combustion those which it brings with it. In the Trubia Arsenal, where the iron and steel produced are used exclusively for artillery, the puddling furnace treats pig iron of the best quality, the process being conducted with extreme care, as the desire is not to produce a large output in a given time, but to produce a metal of superior quality. As the Spanish iron industry deals with pig iron of high grade, the Trubia works employ either coke pig iron from Bilbao or charcoal pig iron from the same locality or from Navarre.

The Trubia puddling furnaces receive five charges of 220 kilogrammes (485 lbs.) each per shift of twelve hours. After these brief observations, the usual mode of working may be described. As is well known, in order to estimate the calorific efficiency of a furnace, it is necessary to determine the quantity of heat available, and that employed or consumed. In the case under consideration, the heat received by the furnace is derived from the following sources:—(1.) The heat of the furnace itself; (2.) the heat of the metal charged into the furnace; (3.) the heat of the producer gases before their combustion is effected; (4.) the heat produced by the combustion of the combustible gases; (5.) the heat of the air which effects the combustion of these gases; (6.) the heat produced by the combustion of the substances which oxidise during the puddling. The heat consumed or utilised will in its turn be composed of:—(a.) the total heat absorbed by the charge up to the point of fusion, the latent heat of fusion, and the heat absorbed from the moment of fusion until the pig iron is converted into malleable iron; (b.) the heat taken up by the slag produced in the operation; (c.) the

evaporation of the water contained in the ore added at the beginning of the charge; (*d.*) the waste heat of the escaping furnace gases; (*e.*) the heat of evaporation of the water of the gas; (*f.*) the reduction of a portion of the ferric oxide, to ferrous oxide, contained in the cinder charged into the furnace and in the ore added; (*g.*) the reduction of a portion of the manganic oxide to manganous oxide, contained in the same materials; (*h.*) the heat that the furnace possesses at the conclusion of the operation; and lastly, (*i.*) the heat taken up by the metal being prepared for the next charge. Assuming that the heat of the furnace is the same before and after the commencement of the operation, the heat due to this source need not be considered. The same may be said of the heat brought by the pig iron charged on the bed of the furnace, and that consumed in pre-heating the metal for the next charge.

It is now possible, therefore, to determine the heat received by the furnace, and with this object in view the data of the problem may be stated thus:—

Weight of pig iron	220 kilogrammes (485 lbs.)
Weight of blooms obtained	195 " (430 lbs.)
Loss	25 " (55 lbs.)
Loss per cent.	11·37
Fuel used	260 kilogrammes (572 lbs.)
Fuel used per 100 kilogrammes of blooms	133·33 kilogrammes.

The coal employed is composed of two-thirds of fine coal from the Mieres collieries and of one-third of lump coal from the Sama collieries. These two coals are mixed, and the following is a bulk analysis of the product:—

	Per Cent.
Moisture	4·61
Ash	8·71
Carbon	73·36
Disposable hydrogen	3·73
Combined water	8·47
Nitrogen	1·12

This coal yields a cinder or residue having the following composition:—

	Per Cent.
Ash	34·85
Carbon	62·23
Hydrogen	0·85
Nitrogen	2·07
Oxygen	2·07

The quantity of this cinder carefully collected and weighed after the operation amounted to 70 kilogrammes.

These data render it possible to calculate with extreme accuracy the quantity of combustible material effectively utilised in the producer.

The composition of the coal being given, it follows that in the 260 kilogrammes there were $73\cdot36 \times 2\cdot60 = 190\cdot736$ kilogrammes of carbon. In the cinder there were $62\cdot23 \times 0\cdot7 = 43\cdot56$ kilogrammes of carbon. It follows that the material actually burnt in the producer was $190\cdot736 - 43\cdot56 = 147\cdot176$ kilogrammes.

Of hydrogen there is in the fuel $3\cdot73 \times 2\cdot60 = 9\cdot698$ kilogrammes, and in the cinder $0\cdot85 \times 0\cdot7 = 0\cdot595$ kilogramme. Hence the quantity of disposable hydrogen amounts to $9\cdot698 - 0\cdot596 = 9\cdot103$ kilogrammes.

It is now possible to determine the different totals that constitute each of the several portions of the furnace balance, taking as basis the calculations made for 100 kilogrammes of blooms, to which 133·33 kilogrammes of coal consumed correspond. And, before passing on, it should be pointed out that the composition of the pig iron puddled and that of the blooms obtained are as follows :—

Pig Iron.

Silicon	3·04
Manganese	1·00
Carbon	3·47
Phosphorus	0·038
Sulphur	0·09
Iron	(92·362)
Total	100·000

Blooms.

Silicon	0·100
Manganese	0·145
Carbon	0·223
Phosphorus	0·007
Sulphur	0·013
Iron	(99·512)
Total	100·000

Heat received by the furnace.—As was pointed out at the beginning of this paper, the two main portions of the account, that is to say, the heat of the furnace at the commencement of

the operation and that of the pig iron when charged into the furnace, need not be taken into account, on the assumption that these two amounts are equal to those which figure in the account of the heat consumed, as the quantities of heat which the furnace retains at the end of the operation, and as the heat acquired by the charge of metal to be puddled in the next charge.

Beginning, then, with the determination of the heat of the producer-gases before combustion is effected, it may be noted that the composition of these gases is as follows:—

	By Volume.	By Weight.
Carbonic anhydride	4.39	8.01
Oxygen	1.99	2.64
Carbonic oxide	14.78	17.16
Hydrogen	11.38	0.85
Nitrogen	67.46	71.34
Totals	100.00	100.00

These figures refer to the gases in a dry state. The moisture met with was about 9.32 per cent. It is evident that, in order to determine the number of calories which the gas carries with it prior to its combustion, it is necessary to know the temperature of this gas. The mean of two determinations of the temperature of the producer was 1025° C. This figure is given with all reserve, as it is well known that little reliance can be placed on figures referring to the specific heat of iron at such high temperatures as that in question. For the determination of this and of the other temperatures, of which a knowledge was necessary in the course of this investigation, a calorimeter was constructed, similar in principle to that of Siemens, capable of containing six litres of water. The temperature of 1025° having been ascertained, it remained to determine the quantity of gas generated in the gas-producer for every 100 kilogrammes of blooms produced, and for every 133.33 kilogrammes of coal consumed. The chemical compositions of the gases and of the coal afford, by means of a simple calculation, the quantity desired. In every 100 kilogrammes of gas there are 9.54 kilogrammes of carbon. Hence the 75.47 kilogrammes of this metalloid burnt in the producer for every 100 kilogrammes of blooms produced give

$$\frac{75.47 \times 100}{9.54} = 791 \text{ kilogrammes of gases. And assuming that the}$$

mean specific heat of these gases is 0.244, it follows that the total number of calories carried to the furnace by the gases will be $791 \times 1025 \times 0.244 = 197,829$ calories.

Heat produced by the combustion of the combustible gases.—The only combustible gases issuing from the producer are carbonic oxide and hydrogen. From the proportion in which these gases occur, and from the quantity of fuel converted into gas, the weight of each of these two gases may be deduced. By a mode of procedure analogous to that already described, these weights are found to be, for carbonic oxide, $17.16 \times 7.91 = 135.73$, and for hydrogen, $0.85 \times 7.91 = 6.72$. The combustion of 135.73 kilogrammes of carbonic oxide will account for $135.73 \times 2403 = 326,159$ calories. That of hydrogen will produce $6.72 \times 29,003 = 194,800$ calories. In this calculation, 29,003, and not 34,462, is taken as the calorific power of one kilogramme of hydrogen, as the former of these two figures expresses the actual number of calories yielded by the combustion of one kilogramme of hydrogen when the product of its combustion is water vapour, uncondensed, at 0°C .

Heat of the air serving for the combustion of the carbonic oxide and hydrogen.—The air necessary for the combustion of the carbonic oxide and hydrogen enters, as has already been stated earlier in this paper, partly through openings in the roof above the fire-bridge, and partly through openings in the fire-bridge itself, so that the gas from the producer on entering the furnace is surrounded by air. The latter carries with it the heat it has taken up in traversing the flues that conduct it to the inlets of the furnace. In order to determine the calories thus introduced by the air, it is necessary to know, (1) its quantity, and (2) its temperature. The quantity was determined from that of the nitrogen contained in the waste gases of the stack. Analysis showed the composition of these gases to be as follows:—

	By Volume.	By Weight.
	Per Cent.	Per Cent.
Carbonic anhydride	13.32	19.96
Water	7.48	4.51
Oxygen	1.42	1.59
Nitrogen	77.78	74.01

These figures refer to the gases in a dry state. The quantity of gases that escape by the furnace-stack must, it is evident, consist of those produced in the gas-producer together with the air that enters to effect the combustion of these gases. Moreover, to these two portions may be added the products of the combustion of the carbon of the pig iron; but this quantity is so very small compared with the total of the other two, that it may be disregarded without sensibly affecting the terms of the problem. From the composition of the gases of the stack, it follows that for every 100 kilogrammes of gas there are 19.96 of carbonic anhydride, which corresponds to $\frac{19.96}{3.67} = 5.43$ kilogrammes of carbon. The quantity of carbon consumed for every 100 kilogrammes of blooms and 133.33 kilogrammes of coal is 75.47 kilogrammes, which yields a quantity of gases equal to $\frac{75.47}{5.43} \times 100 = 1389$ kilogrammes; and that of the nitrogen in the gases will be $1389 \times 0.7401 = 1027.99$. On deducting, as has been said, the nitrogen of the producer gases, the remainder is that of the air. In the producer, for 100 kilogrammes of blooms obtained, 795 kilogrammes of gases are produced, of which quantity 71.34 per cent. is nitrogen, so that $791 \times 0.7134 = 566.70$ kilogrammes is the weight of the nitrogen contained in the 791 kilogrammes of gas from the producer. There remain, then, for the nitrogen of the air $1027.99 - 566.70 = 461.29$ kilogrammes, and this nitrogen corresponds with a quantity of oxygen equal to $\frac{521.29}{3.5} = 148.9$ kilogrammes, giving a total equal to $461.29 + 148.9 = 610.19$ kilogrammes of air. The determination of the temperature of the air presents some difficulty, it not being convenient to insert the iron cylinder in the apertures in the roof or in the fire-bridge. From a number of determinations made during the progress of puddling, the final mean of 550° was obtained.

The specific heat of dry air at constant pressure, according to Regnault, is 0.2379.

From these data it follows that the heat carried by the air to the furnace will be $610.19 \times 550 \times 0.2379 = 80,691$ calories.

Heat produced by the substances that oxidise during the puddling process.—From a comparison of the analyses of the pig iron and of the blooms, the loss being taken into account, it is easy to

deduce the quantities oxidised, not only of the silicon, carbon, manganese, phosphorus, and sulphur, but also of the iron.

Oxidation of silicon.—The total quantity of silicon contained in the 220 kilogrammes of pig iron is $2.20 \times 3.04 = 6.688$. The quantity contained in the 195 kilogrammes of blooms is $0.1 \times 195 = 0.195$ kilogramme. Consequently, the quantity of silicon oxidised is equal to $6.688 - 0.195 = 6.493$, and for 100 kilogrammes of blooms it is equal to $\frac{6.493 \times 100}{195} = 3.33$ kilogrammes.

The oxidation of 3.33 kilogrammes of silicon will give $3.33 \times 7830 = 26,074$ calories, according to Troost and Hautefeuille.

Oxidation of manganese.—Following the same procedure with the manganese as with the silicon, it will be found that for every 100 kilogrammes of blooms 0.983 kilogramme of manganese is oxidised, and the calories produced by this oxidation will be $0.983 \times 2000 = 1966$.

Oxidation of carbon.—The quantity of carbon oxidised for every 100 kilogrammes of blooms is 3.69 kilogrammes, which will yield $3.69 \times 8080 = 29,815$ calories.

Oxidation of phosphorus.—The phosphorus oxidised amounts to 0.035 kilogramme, the combustion of which yields $0.035 \times 5747 = 201$ calories.

Oxidation of sulphur.—Of sulphur 0.088 kilogramme is oxidised, yielding $0.088 \times 2222 = 195$ calories.

Oxidation of iron.—In addition to the oxidation of the substances mentioned, there is also in the puddling furnace a certain amount of iron oxidised. This quantity may readily be determined, as the analyses of both pig iron and blooms are known as well as the loss that occurs. The foreign substances, other than iron, contained in the 220 kilogrammes of pig iron are $6.888 \text{ Si} + 7.634 \text{ C} + 2.200 \text{ Mn} + 0.083 \text{ P} + 0.198 \text{ S} = 16.813$ kilogrammes; those contained in the blooms are $0.195 \text{ Si} + 0.434 \text{ C} + 0.282 \text{ Mn} + 0.0136 \text{ P} + 0.0253 \text{ S} = 0.9499$ kilogrammes. The difference is equal to $16.813 - 0.9499 = 15.8631$ kilogrammes of substances oxidised. As the loss with the 220 kilogrammes of pig iron was $220 - 195 = 25$ kilogrammes, it follows that the iron oxidised during the process was $25 - 15.8631 = 9.1369$ kilogrammes, and for every 100 kilogrammes of blooms this quantity will be $\frac{9.137 \times 100}{195} = 4.68$ kilogrammes. Assuming that

the iron is oxidised to ferrous oxide, the number of calories required for this oxidation will be $4.68 \times 1352 = 6327.36$ calories.

Thus, there has been calculated the total number of calories received by the furnace, and this may be expressed in tabular form as follows:—

Heat Received.	Calories.	Per Cent.
Heat brought by the producer gases	197,829	22.70
Combustion of 135.73 CO and 6.72 H	520,959	59.80
Heat introduced by the air	86,691	9.96
Oxidation of silicon	26,074	2.90
Oxidation of manganese	1,966	0.22
Oxidation of carbon	29,815	3.45
Oxidation of phosphorus	201	0.02
Oxidation of sulphur	195	0.02
Oxidation of iron	6,327	0.72
Totals	870,057	99.79

Heat consumed or utilised.—It has been pointed out earlier in this paper that the heat consumed or utilised in the furnace consists of the total heat received by the charge of pig iron undergoing treatment up to the melting-point, the latent heat of fusion, and the heat taken up from the melting-point until the conversion of the metal into malleable iron, the heat taken up by the cinder produced during the puddling, the evaporation of the water contained in the ore added at the beginning of the charge, the heat carried away by the waste gases, the heat of the aqueous vapour in the gas, the reduction of a portion of the ferric oxide (to ferrous oxide) contained in the cinder charged into the furnace, and in the ore added, the reduction of a portion of the manganic oxide (to manganous oxide) in the same materials, and the heat of the ash.

Heat taken up by the pig iron until its conversion into malleable iron.—Since the final product obtained in the puddling process is malleable iron, the heat taken up by the blooms may be considered to be composed solely of two portions: the latent heat of fusion of the pig iron and the appreciable heat of the blooms. With regard to the latent heat of fusion of the pig iron, if 46 calories are taken per kilogramme of pig iron, 100 kilogrammes of blooms correspond with 112.8 kilogrammes of pig iron, so that $112.8 \times 46 = 5198.8$ calories. The heat of the blooms is

more difficult to determine. From the moment the question is one of determining high temperatures, there is always a difficulty in obtaining the exact figure that expresses the mean specific heat of iron, which is used for the determination of the temperature.

With a view to obtaining as accurate results as possible, use was made of Weinhold's formula :—

$$S = 0.105907 + 0.00003269 (t_2 + t_1) + 0.000000022159 \left(\frac{t_2^2 + t_1^2 + (t_2 + t_1)^2}{2} \right)$$

Employing this formula together with that of the temperature $x = \frac{W+C}{w} (T-t) \frac{1}{s} + t_2$ ("Fuel and its Applications," by E. J. Mills and F. J. Rowan, 1889, p. 345), it was found that the temperature of the blooms was 1160° , and the mean specific heat between 22° and 1160° was 0.173232. Consequently the heat contained in 100 kilogrammes of blooms was $1160 \times 0.173 \times 100 = 20068$ calories.

Heat taken up by the cinder produced during the puddling.—

At the beginning of the process there is charged into the furnace for the renewal of the bed 21.3 kilogrammes of cinder produced on shingling the blooms from previous operations. The chemical composition of this cinder was as follows :—

	Per Cent.
Silica	14.20
Ferric oxide	19.51
Ferrous oxide	58.00
Iron	0.72
Alumina	2.02
Manganous oxide	4.15
Lime	0.71
Magnesia	0.59
Phosphoric anhydride	0.135

Besides this, in renewing the walls of the furnace, 81.5 kilogrammes of powdered ore, obtained from La Mata, in the province of Santander (North of Spain), are used.

The chemical composition of this ore was as follows :—

	Per Cent.
Loss on ignition	13.35
Silica and gangue	13.30
Ferric oxide	63.85
Alumina	0.41
Manganous oxide	7.72
Lime	0.60
Magnesia	0.97
Phosphoric anhydride	0.104

When the process was completed, the cinder produced was collected and weighed. The weight obtained was 144 kilogrammes, of which 121 kilogrammes were obtained from the furnace, and the remaining 23 kilogrammes were contained in the blooms, and were expelled under the hammer. The cinders had the following compositions :—

Description.	Tap-Cinder.	Hammer-Scale.
	Per Cent.	Per Cent.
Silica	14.08	15.78
Ferric oxide	6.33	17.71
Ferrous oxide	67.66	57.76
Iron	0.00	0.69
Alumina	undetermined	3.39
Manganous oxide	5.02	4.31
Lime	0.83	0.71
Magnesia	0.77	0.65
Phosphoric anhydride	0.135	0.188

As must naturally be the case, there is some difference in the composition of the two cinders. There is more ferric oxide and less ferrous oxide in the hammer-scale than in the tap-cinder. This is a matter easy of explanation, owing to its having been more exposed to atmospheric action, which converted a certain portion of the ferrous oxide into ferric oxide. If, then, 195 kilogrammes of blooms give 144 kilogrammes of cinder, for 100 kilogrammes of blooms there will be $\frac{144 \times 100}{195} = 73.84$ kilogrammes of cinder.

Accurate data not being available with reference to the number of calories necessary for the production of a cinder such as that under consideration, nor to its latent heat of fusion, the determination was effected experimentally. For this purpose there was taken from the furnace 0.357 kilogramme of cinder, which was introduced into the calorimeter of which mention has already been made. This contained 6 kilogrammes of water, its value in water being 0.299 kilogramme. The introduction of the fluid cinder caused a rise in temperature of 17.7° . Consequently it may be affirmed that the 0.357 kilogramme of cinder took up a number of calories equal to $17.7 \times 6.299 = 111.49$, and that 1 kilogramme of the same cinder will retain $\frac{111.49 \times 1000}{357} = 312.2$ calories.

The total quantity of cinder corresponding with 100 kilogrammes of blooms was 73·84. Hence the total number of calories in the cinder will be $73·84 \times 312·2 = 23,052·84$ calories.

The quantity of cinder which ought to result from the operation should necessarily be composed of the quantities of cinder and ore charged into the furnace at the beginning of the operation, together with the weights of the impurities oxidised during the furnace operation, with the exception of those converted into gas, less the weight of the oxygen necessary for their oxidation. This is on the assumption that the oxidation of the materials oxidised is effected at the expense of the oxygen of the ferric oxide of the slag and ore introduced into the furnace.

Calculation shows that the cinder produced exceeds by a comparatively large amount that which ought to be formed. The amount of cinder which should theoretically be produced would be that given by the equation $10·92 + 31·852 + 4·545 + 4·7 = 52·017$, in which the first number, 10·92, is the cinder added to the furnace, 31·852 the ore also added, 4·545 is the silicon, manganese, phosphorus, and sulphur oxidised, and 4·7 the iron also oxidised. As will be seen, there is a difference of $73·84 - 52·017 = 21·823$. It is evident, therefore, that the furnace conditions are not the same at the beginning and at the end of the operation, and that this excess of cinder is due to the walls of the furnace. Moreover, the hypothesis is confirmed that the oxidation of the silicon, carbon, manganese, phosphorus, and sulphur is effected at the expense of the oxygen of the ferrous and manganous oxides passing to ferric and manganic oxides. Calculation gives in this way a weight of disposable oxygen of 2·686. If the 21·823 kilogrammes are derived from the lining of the furnace, in this 21·823 kilogrammes there will be $\frac{21·823 \times 63·85}{100} = 13·93$ kilogrammes of ferric oxide, which

in changing to ferrous oxide can yield 1·426 of oxygen. The total quantity of disposable oxygen, therefore, will be $2·686 + 1·426 = 4·112$ kilogrammes. The oxidation of 3·33 of silicon, 1·09 of manganese, 3·7 of carbon, and 4·7 of iron, requires a total of 14·951 kilogrammes of oxygen, and as the cinder will only yield 4·112 kilogrammes, it follows that the furnace gases have had to yield the 10·839 kilogrammes wanting.

Inasmuch as neither the cinder and lining of the furnace nor the gases supply the necessary oxygen for the oxidation of the impurities of the pig iron, although the latter gives, it is true, the larger quantity, the cinders have to serve as carriers of oxygen. Ferrous oxide is converted into ferric oxide, which gives up an equivalent of oxygen, returning to its former state of ferrous oxide. In this way Gruner in his *Traité de Métallurgie* explains the process of wet puddling or pig-boiling.

Vaporisation of the moisture contained in the ore.—As has already been observed, for every 200 kilogrammes of blooms made, 41·8 kilogrammes of ore are employed. This ore does not contain only the hydrates, whose presence is made evident by the loss on ignition shown in the analysis, but it also carries with it a certain quantity of water, added by the puddler before the beginning of the operation. The quantity of water added is 12·34 kilogrammes per 100 kilogrammes of ore, so that the 41·8 kilogrammes of ore contain $\frac{12\cdot34 \times 41\cdot8}{100} = 5\cdot158$. On the other hand, analysis of the ore before the addition of the water and after drying at 120° showed a loss as hydrates of 13·35 per cent. Thus the vaporisation of these hydrates should be calculated on the basis of the ore free from water, that is to say, at 41·8 — 5·158 = 36·642 kilogrammes, and it will then have the value of $\frac{36\cdot642 \times 13\cdot35}{100} = 4\cdot79$. The total quantity of water that has to be vaporised is, therefore, $5\cdot158 \times 4\cdot79 = 9\cdot948$ kilogrammes. And multiplying this quantity by 540 calories, there will be obtained the total number of calories utilised in the vaporisation, which amounts to $9\cdot948 \times 5\cdot40 = 5371\cdot9$ calories.

Heat lost up the stack.—The heat of the gases leaving the furnace is not difficult to calculate when the temperature is known. As a mean of three determinations, verified with the greatest care, there was obtained as a result, which could be accepted without any very grave error, that the temperature of the gases leaving the furnace was 1100°.

The figure 0·240 may be adopted as the mean specific heat of the gases, and as the total weight of these gases for every 100 kilogrammes of blooms is 1389 kilogrammes, the heat carried away by the gases will be $1389 \times 1100 \times 0\cdot240 = 366,696$ calories.

Vaporisation of the moisture of the gas.—The moisture in the 1892.—i.

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gas is, without doubt, derived solely from the water contained in the coal and in the air.

Analysis shows that the coal contains 4.61 per cent. of moisture, and as the quantity of coal burnt per 100 kilogrammes of blooms is 133.33, there will be $133.33 \times 4.61 = 6.14$ kilogrammes of water.

The average proportion of moisture in the air during the day was 0.6 per cent., and as the total quantity of air that left the furnace amounted to 1320 kilogrammes, $13.20 \times 0.6 = 7.92$ kilogrammes was the quantity of moisture due to the air, and the total in the gases was $7.92 + 6.145 = 14.06$ kilogrammes.

Multiplying this amount by 540, there is obtained the number of calories absorbed, namely, $14.06 \times 540 = 7592$ calories.

Reduction of the ferric oxide to ferrous oxide.—There has been used in the furnace operation 10.92 kilogrammes of cinder or hammer-scale and 31.852 kilogrammes of ore. From the analyses of these two substances it may be deduced that in the former there are $\frac{19.31 \times 10.92}{100} = 2.13$ kilogrammes of ferric oxide, and in the latter $\frac{31.85 \times 63.85}{100} = 20.33$ of ferric oxide. Thus the total of the two is $2.13 + 20.33 = 22.46$ kilogrammes of ferric oxide. On the other hand, the cinder resulting from the operation, the quantity of which is 73.84, contains $\frac{73.84 \times 6.33}{100} = 4.67$ kilogrammes, and the difference between the two amounts, $22.46 - 4.67 = 17.79$ kilogrammes, represents the amount of ferric oxide converted into ferrous oxide.

If to this amount is added that corresponding to the 21.823 kilogrammes of ore charged during the operation, the result will be $17.79 + 13.93 = 31.72$ kilogrammes. Applying the law of Dulong, the total number of calories absorbed in the reduction under consideration will be equal to $31.72 \times 4.44 = 140.83$ calories.

Reduction of manganic oxide to manganous oxide.—Applying the same method of reasoning to the manganic oxide as has just been done in the case of the ferric oxide, and taking into account the analyses of the ore and of the cinder resulting from the operation, it will be found that there has been reduced 4.14 kilogrammes of manganic oxide, which should yield 3.726 kilogrammes of manganous oxide and 0.414 of oxygen. The cinder shows 3.70 of manganous oxide, that is to say, an error of 0.026.

This conversion, according to Walter's law, would consume a total of 3344 calories.

Heat of the ash.—The ashes collected in the ash-pit weigh 70 kilogrammes, and for every 100 kilogrammes of blooms the quantity will be 35·89 kilogrammes. In order to determine the number of calories contained in the ash, 0·193 kilogramme was taken and introduced into the calorimeter of which mention has already been made. This amount of ash was found to contain 51·66 calories; consequently per kilogramme of ash there will be $\frac{51 \cdot 66 \times 100}{193} = 267 \cdot 6$ calories, and $35 \cdot 89 \times 267 \cdot 6 = 9604 \cdot 16$ will be the number of calories in the ash.

Heat consumed.—The following summary may be made of the heat consumed :—

	Calories.
Latent heat of fusion	5,198
Heat of blooms	20,068
Fusion of cinder	23,052
Vaporisation of moisture of ore	5,371
Lost up the stack	366,696
Heat of water vapour in gas	7,592
Reduction of Fe_2O_3 to FeO	14,083
Reduction of Mn_2O_3 to MnO	3,344
Heat of ash	9,604
Total	455,008

Conclusion.—As it has been found that the heat produced amounts to 870,057 calories, it is evident that the loss of heat by radiation, and the heat used for heating the air for the combustion of the producer-gases, amount to the enormous figure of $870,057 - 455,008 = 415,049$ calories.

General Balance of the Furnace.

Heat Produced.			Heat Consumed.		
	Calories.	Per Cent.		Calories.	Per Cent.
Heat of producer gas	197,829	22·70	Latent heat of fusion	5,198	2·90
Combustion of 135 CO and 6·72 H	520,959	59·80	Heat of blooms	20,068	
Heat introduced by the air	86,691	9·96	Heat of fusion of cinder	23,052	
Oxidation of silicon	26,074	2·90	Vaporisation of water in ore	5,371	0·60
Oxidation of manganese	1,966	0·22	Lost up stack	366,696	42·14
Oxidation of carbon	29,815	3·45	Vaporisation of water in gas	7,592	0·87
Oxidation of phosphorus	201	0·02	Reduction of Fe_2O_3 to FeO	14,083	1·61
Oxidation of sulphur	195	0·02	Reduction of Mn_2O_3 to MnO	3,344	0·38
Oxidation of iron	6,327	0·72	Heat of ash	9,604	1·11
			Radiation and heat of air	415,049	47·70
	870,057	99·79		870,057	99·95

From this statement it will be seen that the heat actually utilised in the puddling furnace is only 2.9 per cent. This result should not be considered surprising if the short length of these furnaces is taken into account. Indeed, in such furnaces it may be said that the gases leave at the same temperature as that at which they entered the furnace. Under the special conditions of work obtaining at the Trubia Arsenal, where iron of first-class quality is exclusively made, the puddling operation lasts a considerable time, and the consumption of coal is proportionately large. The gases on leaving the furnace are utilised for the production of steam.

The results obtained in this investigation are given merely as approximations, so many difficulties being presented in the accurate determination of high temperatures. The analyses were made with the utmost care by Mr. Wolff, the able chemist at the Arsenal.

APPENDIX.

THE IRON AND STEEL INSTITUTE.

STATEMENT OF ACCOUNT FOR THE YEAR ENDING DECEMBER 31, 1891.

RECEIPTS.		EXPENDITURE.	
To Investments—December 31, 1890	£8012 8 11	By Balance due to Treasurer, December 31, 1890	£733 4 0
„ Entrance Fees	£159 12 0	„ Salaries of Secretary and Clerks	342 10 1
„ Subscriptions	3063 18 0	„ Office Rent, Cleaning, &c.	15 15 0
„ Journals and Indexes sold	224 12 6	„ Purchases for Library and Office Furniture	7 7 0
„ Interest	278 12 4	„ Secretary's Travelling Expenses	156 6 0
„ Bessemer Medal Fund Interest	13 12 0	„ Editing and Translating	32 4 0
„ Balance due to Treasurer.	3742 6 10	„ Expenses in connection with Annual Meeting	140 16 2
	403 3 2	„ Expenses in connection with Meeting in London, October 1891	812 2 8
		„ Journal Publishing Expenses	10 0 0
		„ Payment on Account of Special Journal to America, October 1890	64 15 4
		„ Index to Proceedings of the Institute	233 9 3
		„ Printing, Advertising, and Stationery	1 2 4
		„ Insurance	15 5 0
		„ Bessemer Medal	18 14 6
		„ Inland Revenue Corporation Duty	121 6 1
		„ Postages, Receipts, &c., per Treasurer and Secretary	67 9 4
		„ Sundry Payments	2767 6 11
		„ Investments—	
		„ In £115 North-Eastern-Darlington 5½ per cent. Stock, at a cost of	£1738 8 9
		„ In £1081 North-Eastern 1876 4 per cent. Preference Stock, at a cost of	1998 19 7
		„ In £630 North-Eastern Darlington A. 5 per cent. Stock, at a cost of	1003 14 0
		„ In £1546 Schude, Funjaub, and Delhi 5 per cent. Stock, at a cost of	1999 0 7
		„ In £750 Great Indian Peninsula Railway 5 per cent. Stock, at a cost of	1267 6 0
			8012 8 11
			£12,157 18 11

(Signed) DAVID DALE, Hon. Treasurer.
May 14, 1892.

* This has since been compulsorily converted into an Annuity up till 1908, with a Sinking Fund to replace the amount of Stock, £1546.

Income	£12,157 18 11
Expenditure	£3742 6 10
Surplus	2767 6 11
But this is subject to a further expenditure on the American Volume, estimated at	974 19 11
Thus reducing the surplus to	810 0 0
	£104 19 11

NOTES

ON THE PROGRESS OF THE

HOME AND FOREIGN

IRON AND STEEL INDUSTRIES.

I.—1892.

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ABSTRACTORS.

EDWIN J. BALL, Ph.D.

BENNETT H. BROUGH, Assoc. R.S.M.

IRON ORES

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I.—OCCURRENCE AND COMPOSITION.

Genesis of Iron Ores by Replacement of Limestone.—Mr. J. P. Kimball * shows that the well-recognised products of epigenesis, like siderite and ferro-calcite, are, as a rule, also products of direct pseudomorphous replacement of isomorphous calcium carbonate. From this it follows that secondary or indirect replacement of calcium carbonate by ferric hydrate is wrought through alteration of pseudomorphous siderite or ferro-calcite, and also, through progressive alteration, by ferric oxide, and even by magnetic oxide. As the result of his investigations, the author advances the proposition that deposits of concentrated iron ores occur far more extensively as pseudomorphous replacements than has hitherto been made to appear, and far more extensively than by original sedimentation of ferric hydrate.

In a subsequent paper † Mr. J. P. Kimball proceeds to instance a number of examples illustrating the general points under discussion. The samples selected to show the genesis of iron ores by isomorphous and pseudomorphous replacement of limestone are as follows: (1.) Iron ores of the Sub-Carboniferous limestone of Eastern Kentucky. (2.) Replacement of coral-rock (limestone) on the Eastern Peninsula of Cuba. (3.) Replacement of Carboniferous and Silurian limestones in Colorado. (4.) Replacement of Upper Silurian (Clinton) limestones in the Appalachians of Southern Pennsylvania. (5.) Replacement of Carboniferous limestone. (6.) Limonites of the Lower Silurian limestones. (7.) Replacement of crystalline iron ores at Cornwall, Pennsylvania; and (8.)

* *American Journal of Science*, vol. xlii. pp. 231-241.

† *The American Geologist*, vol. viii., December.

Replacement of Cambrian Limestones in the Lake Superior region and Missouri. He concludes with a few illustrations of replacement of limestone by iron ores in important European localities. As such, most of these have been distinctly recognised. The illustrations selected are : (9.) Replacement of Carboniferous limestone in the North of England. (10.) Replacement of Mesozoic limestones in Northamptonshire and Yorkshire. (11.) Replacement of Liassic limestone in Luxemburg and Lorraine. (12.) Replacement of Mesozoic limestones in Central France. (13.) Replacement of Tertiary limestone in Hesse. (14.) Replacement of Prepalæozoic crystalline limestone in the Banat. In conclusion, the author shows that the iron ores of Bilbao, of Elba, and of Algeria, as well as those of Carinthia and of Siegen, furnish abundant evidence of having been formed by replacement of limestone.

The Formation of Iron Ore Deposits.—Dr. A. Irving,* discussing the action of organic matter as an agent of transfer and deposition, points out that ferric oxide and manganese oxides are most extensively deposited by the agency of organic acids. The limonite raked up in Canada and in Sweden from the beds of shallow lakes is precipitated in the shallow waters after having been brought down from the upland regions of Archæan rocks, the surface waters from which are charged with humus acids from morasses and forest litter. Perhaps one of the most interesting phenomena resulting from action of these acids is the formation of pseudomorphs of oxide of iron as casts of calcareous fossils. The Northampton iron ore furnishes well-known examples of this.

Bog iron ore is by no means always pure limonite. Accessory materials, notably phosphate and silicate of iron, are found in addition to the limonite, and small quantities of lime, magnesia, alumina, and manganese are of common occurrence. In many instances, owing to incomplete oxidation, the humus acids themselves are found as impurities in the form of basic salts. In the Swedish lake ores traces of chromium, arsenic, molybdenum, nickel, cobalt, zinc, and other metals are recorded. In a state of fresh precipitation, the ochreous marsh and lake ores may even contain ammonia. There can be scarcely any doubt that the silicate of iron often found in bog iron ore was once held in solution by the agency of humus acids, and it is highly probable that a good deal of such silicate, while in solution, has undergone decomposition by the action of carbonated water at no great depth.

* *Proceedings of the Geologists' Association*, vol. xii. pp. 227-238.

The Iron Ore Beds of Northamptonshire.—The record of the excursion of the Geologists' Association to Northamptonshire * contains a detailed description of the beds in that area, illustrated by a section showing the sequence of beds in the neighbourhood of Northampton, a section from Duston to Dallington, and a reproduction of a photograph of a section at Stowe Nine Churches.

The ironstone beds vary much in thickness, in the quantity of iron in them, and in the mode of its occurrence. Most of the Inferior Oolite fossils are found in these beds, though where there is much iron they are chiefly casts only. At Duston the iron ore has been dug without intermission for a great number of years. Sometimes a depth of nearly 25 feet can be utilised; but more often the uppermost and lowest beds are rejected, the former being sandy and poor, and the latter containing phosphates. The character of the best ore is peculiar, consisting of nearly rectangular, or it may be oval, concentric boxes of rich dark iron ore in the condition of limonite, with cores of ochreous or green mineral. This is mostly carbonate of iron with some silicate, and in the lower beds about 2 per cent. of phosphate of iron, giving it a bluish tinge. The latter ore is thrown on one side. The proportion of iron in the workable ore varies from 25 to 30 per cent., though the casings contain more and the cores less than these amounts.

The probable source of the iron in these beds has given rise to much discussion. The most satisfactory explanation appears to be that the organic acids produced by decomposing vegetable matter in the estuarine beds above, gradually attacked the iron-containing minerals of the beds in which they occurred, and of those below, dissolving the iron, and thus leaving the upper layers bleached as white sand. The impervious Lias clay kept the ferruginous water in contact with the lower beds, so that as the hydrostatic pressure forced the solution along the lines of least resistance in these lower layers, lime was gradually replaced by iron in the beds, and iron by lime in the water. Oxygenated water finished the operation, and produced the hydrated peroxide now met with.

The Iron Ores of France.—According to M. D. Danton † there were analysed at the School of Mines at Paris, between the years 1845 and 1877, 1539 samples of iron ores from seventy-seven departments of France and three of Algeria. From these analyses he deduces the

* *Proceedings of the Geologists' Association*, vol. xii. pp. 172-190.

† *Bulletin de la Société de l'Industrie Minérale*, vol. v. p. 311.

following conclusions:—(1.) The average percentage of iron in the iron ores of France and Algeria is 45; thirty-eight departments contain ores of lower grade, and thirty-nine departments ores of higher percentage. The richest ores, with from 67 to 70 per cent. of iron, are from Algeria. (2.) Manganiferous ores are found in forty departments, but, with the exception of the ores of the Pyrenees and of Algeria, the percentage of manganese is very low. (3.) The iron ores are usually more or less phosphoric. The phosphorus, however, does not exceed, as the average proportion, 0·13 per cent.; and of the 1539 samples examined, 406, or more than 25 per cent., contained only traces of phosphorus. The highest percentage of phosphorus occurs in the iron-stone of the Marne and Orne, in the east of France, on the German border. In ores from this district the proportion of phosphorus has sometimes reached as much as 5·52 to 5·80 per cent. These figures, however, appear open to doubt.* (4.) Sulphur is a less frequent constituent of French iron ores than is phosphorus. Of 1539 samples examined, 710, or almost one half, contained no weighable quantities of sulphur. The average percentage of sulphur in the remainder of the samples was 0·20.

The Iron Ore Deposits of South-West Vogtland.—A. Buchrucker † observes that Vogtland is one of the oldest of the iron ore producing districts of Germany, and is for the greater part a portion of the principality of Reuss, a small part belonging to the kingdom of Bavaria. The greater extent of the south-western portion is traversed by a so-called greenstone dyke, surrounded by Devonian and Silurian slates, with beds of grauwacke and siliceous slate. At the northern end of the greenstone, a Devonian limestone is met with, and here there are considerable deposits of red hæmatite and of highly manganiferous brown iron ore. These ores occur mainly as contact deposits, either between the greenstone and the limestone, or between the greenstone and the slates. Near Lobenstein true iron ore veins are met with crossing the clay slates and the greenstone, but coursing in places between the greenstone and the slate. The lode material consists of spathic iron ore, brown iron ore, quartz, manganese carbonate, ankerite, and breunnerite, spathic ore being the main constituent, converted into brown iron ore at the surface. Both ores are very pure and rich in manganese. A few of these lodes contain nickel in workable quanti-

* *Stahl und Eisen*, vol. xii. p. 319.

† *Ibid.*, vol. xi. p. 911.

ties. Some of them have been followed along their strike for over a mile. Formerly the ore deposits of this district were worked on a considerable scale, owing to the existence there of a number of charcoal furnaces. These had gradually to be abandoned, owing to competition with coke furnaces, and the absence of railway communication has since rendered the ore deposits unavailable. Now, however, several railways are either built or in course of construction, and the district is likely to again become of importance.

The Iron Ore Deposits of Eastern Spain.—J. Pie y Allué * discusses the value of the iron ore deposits of Almería and the eastern portion of Spain generally. It is customary to speak of the iron ore "veins" of Alfaro, Los Baños, Lucainena, Bédar, Bacares, Sierra de Enmedio, Mórata, &c. Nothing, the author observes, can be more inaccurate. True iron ore veins are comparatively rare in the province of Almería, though some are found at Beires; they are of no great importance, and are not likely to be worked. The deposits of the Alhamilla, Bacares, and Bédar ranges, to which reference has been made above, and those of the Enmedio range, of Mórata, Parazuelos, Carrascoy, and other localities are found, like others in Almería and Murcia, in limestones and dolomites. These the author considers to be bedded deposits. They do not extend beyond the limestones or dolomites, giving out when these make contact with the slates or adjacent rocks. Some of the beds are very highly inclined, while others are nearly vertical. Wherever met with, the ore shows but slight differences in composition. Fossils are found in some of them, and they all appear to be of aqueous origin. The limestones are of very different horizons. Some are triassic; in other ore deposits in the limestones, Pliocene fossils are met with converted into pyrites or iron oxide, pointing to an earlier origin for the iron ores than the age of the limestones with which they occur. In tracing the ore deposits, it must be borne in mind that if slate or other country has to be passed through, no ore will be met with—the limestone must be followed throughout. Details as to the various deposits are not given by the author, who simply deals with their origin.

Spanish Iron Ore Mines.—R. Oriol † states that the iron ore mines of the Asturias are increasing rapidly in number, although the

* *Revista Minera, Metalúrgica y de Ingeniería*, vol. xlii, pp. 377-379.

† *Ibid.*, vol. xliii, pp. 177, 178.

ore is less pure and more refractory than the Bilbao ores. The deposits consist principally of Devonian, Silurian, and Cambrian quartzites, impregnated with iron oxide somewhat high in phosphorus. The mines of Mórata, in the province of Murcia, have recently been connected with a port by a narrow-gauge line. These mines are being worked by an English company. Large quantities of magnetic iron ore have been exported to the United States from the mines of Marbella, in Malaga, as much as some 180,000 tons having been so exported in 1891. Other magnetite deposits are stated to exist more towards the centre of the province of Malaga, but a railway must be built before they could be worked. The important deposits of manganiferous iron ore at Las Herrerias, in Almería, have not been worked for the past twenty years, but work on them is about to be resumed on a large scale, the water having now been raised from the old workings, and a large wall having been built to prevent the workings being again drowned by overflows of the adjacent Almanzora river. This Herrerias deposit is known to extend for over 1000 yards in length, with a thickness exceeding 40 yards. It was worked in very ancient times for silver, the manganiferous iron ore being also argentiferous.

Referring to a statement which had been made in a London journal as to the existence of enormous undeveloped deposits of very pure iron ore in the Asturias—iron ore similar to the campanil of Bilbao—the *Revista Minera** states that this information is inaccurate. Unfortunately no such deposits exist, the ores found being very impure. Thus in the mines adjacent to the Trubia Arsenal, although a little pure ore is found, the quantity forms but a small proportion of the whole. The Asturias can never hope to become an exporting district for pure ore, and where the basic process is not in use, the Asturias ores, if smelted in Asturias, must be mixed with Biscaya ores. With regard to the statement that large steelworks are to be established at Mieres, this also is inaccurate, as the working will only be on the scale of a test. With regard to the coal deposits of Asturias, one of the main difficulties connected with their development lies in the absence of shipping ports.

Spanish Iron Ores.—The following are analyses of iron ores exported from the north of Spain : †—

* Vol. xlii. p. 373.

† *American Manufacturer*, vol. I. p. 10.

Description.	Iron.	Manganese.	Phosphorus.	Silicon.
Portman ore	50	...	0·04	...
Manganiferous ore	30	15	0·04	11
Manganiferous ore	25	17	0·04	11
Low grade manganiferous ore .	45	5	0·03	8

Swedish Iron Ores.—About 150,000 tons of ore from the Grängesberg mines, Sweden, are exported annually from Oxelosund and Gothenburg to Silesia and Rhenish Westphalia. Analyses of these ores gave the following results : *—

	I.	II.	III.	IV.
Silica	2·65	2·76	6·07	2·06
Ferric oxide	59·20	79·64	57·36	63·90
Ferrous oxide	27·40	9·64	26·26	29·11
Alumina	2·85	1·29	1·58	1·82
Manganous oxide	0·36	0·14	0·24	0·06
Lime	3·24	3·38	3·39	1·98
Magnesia	0·94	1·41	2·07	0·64
Phosphorus	0·982	0·881	0·870	0·547
Sulphur	0·073	0·016	0·041	trace
Metallic iron	62·78	64·02	60·56	67·38

The Morawitzka Magnetite Mine.—At Morawitzka, in Southern Hungary, iron ores occur in large irregular masses in granite. The ores consist of magnetite, red hæmatite, and iron glance. The magnetites contain :—

Ferrous Oxide.	Ferric Oxide.	Manganese Oxide.	Silica.
22·3-39·8	57·4-62·8	1·0-3·0	11·4-16·0
Alumina.	Lime.	Magnesia.	Carbonic Anhydride.
1·6-4·1	1·3-2·9	0-2·9	1·2-1·6

The red hæmatites contain :—

Ferric Oxide.	Ferrous Oxide.	Silica.	Alumina.	Lime.	Manganese Oxide.
75·2	3·6	9·0	3·2	3·7	1·7

and the iron glance contains 66·7 per cent. of ferric oxide and 10·6 per cent. of ferrous oxide. At the mine 800 to 900 workmen are employed. The output amounts to 98,000 tons annually, of which 75 per cent. is magnetite.†

* *Stahl und Eisen*, vol. xii. p. 9.

† *Glückauf*, 1891, No. 61.

The Iron Ores of Central Russia.—P. A. Zemjatschensky * has made an exhaustive geological and chemical examination of the iron ores of a portion of the Moscow coalfield. These ores occur in pockets and beds in clays of various descriptions. In the clay beds there also occur concretions of silica and flints, sometimes containing fossils of Carboniferous or of Permian age. The iron ores consist of brown iron ore and sphaerosiderite. They occur mostly in the deeper portions of the clay beds, not far from the contact of the clay and the underlying limestones. The ore deposits are from 6 feet to 20 feet in thickness. The author gives numerous analyses of the ores, one of which, the ore from Katnoff, has the composition, not of brown iron ore, but of Hermann's turjite or hydrohæmatite, the analytical results being as follows :—

Fe_2O_3 .	H_2O .
93·94	6·06

and the formula $2\text{Fe}_2\text{O}_3\cdot\text{H}_2\text{O}$. The mineral has a dark red colour with a blue tarnish. Its hardness is $4\frac{1}{2}$, and its streak is of a cherry-red colour. It is, in fact, exactly similar to the turjite found at the Turjin mine in the Ural.

In the ores from Dankoff, in some very dense brown iron ores, crystals of a ferric hydrate occur, to which the author assigns the name of hydrogoethite. Its specific gravity is 3·556, and its chemical formula $3\text{Fe}_2\text{O}_3\cdot 4\text{H}_2\text{O}$, the analytical results being as follows :—

SiO_2 .	H_2O at 100° .	H_2O .	Fe_2O_3 .	$\text{Al}_2\text{O}_3 + \text{P}_2\text{O}_5$.
0·82	0·88	12·03	78·02	8·25

The same mineral is met with in the ores in the vicinity of Lipezk.

The Iron Ores of Ufalejsk, Russia.—A. Stuckenberg † gives a geological description of this very wild and thinly populated portion of the Ural Mountains. Iron ores are widely distributed. Specular iron ore with brown and red hæmatite occur in mica schist on the river Scheleja; magnetite occurs in chlorite schist on the river Bykoffka, with magnesite on the river Generalka, and also in talc schist. Brown hæmatite occurs mostly in highly weathered talc schist at the contact with marble and quartzite.

The Ore Deposits of Miednorudjansk and Wyssokaja.—P. Gladkij ‡ notes an interesting connection between the occurrence

* *Trudy Peterbourgskago Obščestva Estestvoispytatelj*, vol. xx. pp. 1-300.

† *Materialy dia Geologii Rossii*, vol. xiii. pp. 53-94.

‡ *Russian Mining Journal*, vol. i. pp. 96-123.

of magnetite and copper ores in the Central Ural. Magnetite frequently, for example, at Blagodan, contains copper pyrites, and the magnetic iron ore of Wyssokaja is even smelted for copper. The copper ores at Miednorudjansk have been formed by the precipitating action of limestone on the cupreous solution formed by oxidation from the cupriferous magnetite.

The Iron Ores of Nova Scotia.—A very full account of the iron ores of Nova Scotia is given by Mr. E. Gilpin,* and the description is accompanied by a large number of analyses and by two maps. A short historical account is first given, from which it appears that the presence of iron ore was first reported in 1604, but no attempt was made to use the ores till the beginning of the present century, since which time several furnaces and works have been started with varying success.

The following table is given to show the age of the various ores found :—

<i>Geological Age.</i>		<i>Variety of Ore found.</i>
Modern	.	Bog ore, iron sand.
Triassic	{ Sandstone Trap }	Magnetic, specular.
Permo-Carboniferous	.	Clay ironstone.
Carboniferous.	{ Upper Coal measures True Coal measures Marine limestone Lower Carboniferous }	Clay ironstone. Black band, clay ironstone. { Clay ironstone, spathic. Limonite, red hæmatite. Red hæmatite.
	Devonian, Oriskany sandstone, &c.	{ Red hæmatite, magnetite. Spathic, specular ore.
	Upper Silurian { Clinton Lower Helderburg }	Red hæmatite.
	Lower Silurian	Red hæmatite, magnetite.
Cambro-Silurian	.	Specular, limonite.
Laurentian	.	Red hæmatite, specular.

All the divisions of the Carboniferous formation carry clay ironstone, but the deposits, with one exception, have not as yet proved of economic value. The author then proceeds to deal in detail with the ores as they occur, passing from east to west, dealing first of all with the Island of Cape Breton. Analyses of some of these ores show :—

* *Transactions of the Canadian Society of Civil Engineers*, vol. v. pp. 97-119.

	Loch Lomond.	East Bay.		Whycocomagh.		Loran.	Big Pond.	Georges River.
Metallic iron .	61.49	59.52	57.92	48.25	60.90	63.09	61.39	62.50
Silica .	7.76	5.13	12.80	24.78	10.80	5.45	9.04	7.82
Phosphorus .	0.03	...	...	trace	trace	...	trace	0.09
Sulphur .	0.07	0.07	trace	trace	trace	0.10	trace	trace
Phosphoric acid .	...	0.03	0.16	...	...	0.11	...	...
Alumina .	...	...	1.55	2.72	1.40	...	...	...
Magnesia .	...	...	0.80	1.08	1.64	4.20	1.22	0.88
Lime .	...	...	1.20	1.18	1.35	...	...	0.67
Water .	...	...	1.30	1.30	...	...	1.53	1.10
Manganese .	2.85	...	0.26	...	...	...	...	...

In Pictou County, in Nova Scotia proper, there are several large deposits, and some of the ores in this district are shown below :—

	Specular.			Limonite.		Red Hematite.	
Oxides of iron .	92.01	64.03	97.52	93.09	81.19	70.00	65.26
Oxides of manganese	2.16	2.74	...	1.10	0.20	...	trace
Alumina .	0.21	2.95	...	...	...	...	5.59
Carbonate of calcium	1.27	0.041	...	0.01	0.63	3.03	1.88
Carbonate of magnesium	0.43	0.046	...	...	...	...	1.05
Phosphoric acid .	0.08	0.031	...	...	0.15	0.20	...
Sulphur .	0.16	trace	0.06	0.04	trace	...	...
Silica .	3.68	17.89	8.20	4.80	4.26	25.82	25.68
Metallic iron .	64.41	44.82	68.33	65.20	56.83	45.47	43.40

At Londonderry there are two furnaces, and two kilns are being built to calcine spathic iron ore containing 40.60 per cent. of iron, 1.60 of silica, and 32.8 per cent. of volatile matter. The flux used is free from sulphur and phosphorus, and the iron made here had the following composition :—

Carbon.	Silica.	Sulphur.	Phosphorus.	Manganese.	Iron.
3.50	0.84	0.02	0.19	0.44	94.85

From the Bay of Fundy ores are obtained containing :—

Iron .	60.430	49.291	68.33
Silica .	14.430	26.872	5.46
Phosphorus .	0.036	0.031	...
Sulphur .	0.046	0.021	...
Titanic acid .	trace	trace	...
Magnesia .	...	...	1.27

At Torbrook, ores used for the Londonderry furnaces have been raised, and the following analysis shows their quality :—

	Magnetite.	Magnetite.	Red Hæmatite.
Metallic iron . . .	59.11	57.93	59.86
Sulphur	0.09	0.036	0.11
Phosphorus . . .	0.17	0.16	none
Alumina	5.53	...	3.14
Lime	2.70	...	2.16
Magnesia	0.41	...	...
Silica	14.97	17.21	5.93

Besides the above, a large number of other localities are mentioned.

The Iron Ores of the Marquette District, Michigan.—It will be remembered that Professor R. D. Irving * maintained that the ores, jaspers, and associated rocks of Lake Superior are derived directly or indirectly from the alteration and silicification of an original iron-bearing carbonate. A detailed study of the Penokee-Gogebic district led Mr. C. R. Van Hise † to the conclusions that the original rock of the iron-bearing formation was a cherty carbonate of iron, magnesium, and calcium, and that the varieties of rock now found in this formation, such as chert, jasper, schists, and ore, are all produced from this original carbonate by various alterations.

Thinking that it was probable that the same principles of concentration are applicable to other districts, Mr. C. R. Van Hise ‡ has now made a systematic investigation of the entire Marquette district. In this district the ore deposits occur in two formations separated by a great unconformability. The ore deposits of the upper series are much less important than those of the lower.

The ore deposits of the Lower Marquette series all occur in, or are associated with, a single formation, consisting of bands of nearly pure silica alternating with bands of oxides of iron. When the quartz is free from oxide of iron, it has a white colour, and is usually called chert. When the exteriors of the quartz granules are stained with hæmatite, the material is called jasper. Near the top of the formation the silica is nearly all jasperised. The remaining important variety of rock associated with the ore is magnetite-actinolite schist. Recent study has shown that iron carbonate is also an important constituent of the ore-bearing formation. It is believed that the cherty carbonate of iron is the original source of the various forms of ferruginous rocks occurring in the ore-bearing formation. Associated with the ore deposits are two other classes of rocks, the overlying conglomerate and

* *Journal of the Iron and Steel Institute*, 1887, No. I. p. 314.

† *Ibid.*, 1889, No. I. p. 230.

‡ *American Journal of Science*, vol. xliii. pp. 116-132.

quartzite of the Upper Marquette series, and eruptive rocks, diabases and diorites, in bosses and in dykes.

The known Lower Marquette ore deposits may be divided with reference to their position into four classes:—(1.) Deposits at the contact of the quartzite-conglomerate and the ore-bearing formation; (2.) deposits resting upon soap-rock which grades into massive diorite; (3.) deposits resting upon dykes of soap-rock, which follow along or cut across the ore-bearing formation; (4.) deposits interbedded in the jasper or chert.

The ores of the first class are generally hard, and either specular or magnetic. One of the largest deposits of this class is at the Republic mine. The ore deposits of the second, third, and fourth classes are usually soft. While the ore deposits of the Lower Marquette series have a greater variety of form and relations than those of the Penokee district, it is evident that the conditions governing their formation are much the same. It is, therefore, thought that the explanation of the origin of the ores in the Penokee district is applicable, with few modifications, to those of the Marquette district, although the larger number of deposits of the latter belong to an older series. The form, position, and relation of the ore deposits render it evident that the origin was not eruptive. It is equally certain that these irregular masses of ore were not produced directly by sedimentation. All the facts bear towards the conclusion that the ore is a secondary concentration produced by the action of water percolating downwards.

In order to produce the ore, two things must have occurred:—(1.) The concentration of iron oxide in the places where the ore bodies are found; and (2.) the removal of silica from these places. The concentration of all the ores occurred, the author is of opinion, during and later than the folding and erosion subsequent to Upper Marquette time.

The ore deposits of the Upper Marquette series, so far as studied, show that the original material was an iron carbonate, and that the ores are secondary concentrates resting upon impervious formations. The same view applies to the other iron-bearing districts of Lake Superior.

The Iron Ore Deposits of the Mesaba Range.—The ore bodies of this district are defined by greenstone belts, having no continuity, but the same general direction.* The ore formation lies close to and

* *American Manufacturer*, vol. 1. p. 200.

south of the greenstone, which is used as a guide. In some places this courses almost in a semicircle, but more to the west it approaches a straight line. There are several of these greenstone belts. The formation has a dip of 12° , the ore lying upon a quartzite similar to the footwall quartzite of the Gogebic deposits, and occurring in lenses or pockets of varying size. Nine-tenths of the work as yet done on this range has been performed since the autumn of 1891. The ore bodies lie almost horizontally, simply covered with a thin bed of gravel or a light sandstone cap. Millions of tons of ore have been exposed, although, as yet, neither a boiler nor a winding engine has been employed. For years to come the cost of mining will not exceed two shillings a ton, as all that has to be done to lay bare from 30 to 40 tons of ore is to remove from 15 to 20 cubic yards of gravel, at a cost of about fourpence per yard. The ore is an excellent Bessemer ore, extremely low in phosphorus. The extent of the ore of the Mesaba Range is very great, but 30 miles is about the limit of the explorations of the western range. There, to the west, the ore is nowhere found at less than 60 feet from the surface, and it has thinned down to 6 feet or less.

Mr. H. V. Winchell,* the Assistant State Geologist of Minnesota, in an official report on the iron ore deposits of the Mesaba Range, observes that it is the richest ore-bearing district in the United States, and the one most cheaply mined. It is 25 miles nearer Duluth than is the Vermilion Range. The ore occurs in beds, having a dip to the south of from 12° to 40° with the horizon. The formation extends from the Mississippi River to the Canadian boundary-line, about 140 miles. Over this entire distance there are outcrops of the Huronian formation containing beds of iron ore. To the east of the Duluth and Iron Range Railway the ore is covered by gabbro to such a depth that diamond drilling will be needed to determine its value. West of the railway the overburden is but a few feet in thickness. Under this, sheets of ore from 40 to 80 feet in thickness are met with, and but little water is encountered. The ore is so soft that it can be mined by means of a steam-navvy. The quality of the ore is stated not to be equal to that of the Vermilion district. Still it is very pure, containing very little phosphorus and about 60 per cent. of iron. The greatest development is in Township 58-16.

At the Biwabik mine, fourteen test-pits have been sunk within an area of 1400 feet by 1200 feet, and eleven of these have shown ore

* *American Manufacturer*, vol. 1. p. 329.

varying from 25 to 80 feet in thickness. Assuming an average thickness of 40 feet, this would show a total quantity of ore in sight equal to 7,000,000 tons. The test-pits vary in depth from 12 to 97 feet.

Mr. C. F. Howe* states that the ore of the Mesaba Range is similar in character to the Gogebic ores. As a rule, it is a soft Bessemer hæmatite, that can be mined almost without the use of explosives. It occurs in enormous quantity. A railway 75 miles in length is being built from Duluth, Lake Superior, to open up this new iron ore field.

The Vermilion Iron Ore Range.—The output of the mines of this range in 1891 has been considerable. The shipments of ore from the Minnesota mine amounted to 517,817 tons, and from the Chandler mine 372,728 tons. The Pioneer mine exported 3080 tons. The total was thus 892,995 tons. The composition of the ore shipped was as follows: †—

Ore.	Iron. Per Cent.	Phosphorus. Per Cent.
Minnesota	62 to 69	0·04 to 0·06
Chandler	64	0·038

Iron and Manganese Ores in Indian Territory.—A description is given by Mr. B. A. Ludgate ‡ of the manganese ore belt lying about fifteen miles west of Lehigh in Indian Territory. The ore is found in the Lower Silurian limestone, or between it and the Middle Silurian limestone. The general characteristics of the deposits are said to be similar to those of Cuba and Chili. The ore is found in pockets, and consists of black oxides and of carbonates of manganese with calcite, and in some instances with bitumen. Analyses of the black oxides have shown—

Mn.	Fe.	SiO ₂ .	P.
63·50	1·23	0·35	0·023
51·43	2·90	0·89	0·042

An analysis of ore from several large piles showed—

Mn.	Fe.	SiO ₂ .	P.	CaO.	H ₂ O.
42·95	5·95	1·49	0·05	9·75	8·5

The carbonates contain from 25 to 44 per cent. of manganese, and

* *Iron Age*, vol. xlviii. p. 895.

† *Engineering and Mining Journal*, vol. liii. p. 93.

‡ *Bulletin of the American Iron and Steel Association*, vol. xxv. ; *Iron*, vol. xxxviii. p. 490.

are generally low in phosphorus, silica, and iron, and sulphur has only been found as a trace. The ore belt can be traced for fifteen miles, and is within a mile of both coal and limestone. Analyses of the iron ore gave—

Silica.	Iron.	Manganese Oxide.	Sulphur.	Phosphorus.	Titanic Acid.
5.98	64.58	0.11	0.029	0.018	0.40
4.88	57.81	0.11	0.043	0.061	...

A pure limestone is also found in the neighbourhood.

Iron Ores in Kentucky.—Mr. W. B. Phillips* states that the ore found near Eddyville, Kentucky, contains about—

Iron.	Silica.	Phosphorus.
50	7 to 12	0.2

The percentage of phosphorus is very variable. Two new charcoal furnaces are to use the ore; their capacity is about 70 tons a day. Charcoal is cheap, and limestone exists in the neighbourhood of the ore deposits.

New Jersey Magnetite.—Mr. H. J. Detwiller† publishes the following average analysis of the magnetite ore mined at Weldon, New Jersey—

	Per Cent.
Metallic iron	58.960
Manganous oxide	1.270
Lime	2.720
Magnesia	0.690
Alumina	1.370
Phosphorus	0.264
Sulphur	0.014
Titanium	0.960
Silica	7.010

This analysis represents the average analysis of the monthly shipments of ore during the space of one year.

Magnetic Iron Ore in North Carolina.—An account is given by Mr. H. B. C. Nitze‡ of the deposits of magnetic iron ore in Granville County, North Carolina. The deposits consist of lenticular ore bodies lying conformably between slate walls in the Huronian formation. The strike is about north-east by south-west, and the dip is high towards the south-east. The ore consists of red hæmatite, partly

* *Iron Age*, vol. xlviii. p. 61.

† *Ibid.*, vol. xlviii. p. 538.

‡ *Engineering and Mining Journal*, vol. liii. p. 447.

magnetic, with streaks of pure, coarsely crystalline specular ore. It is compact, hard, and fine-grained, with a gangue of quartz and slate. Openings have been made at three points, exposing thicknesses of ore of $7\frac{1}{2}$ feet, 21 feet, and 18 feet respectively. Analyses show—

Silica.	Iron.	Sulphur.	Phosphorus.
17.82	52.48	0.006	0.097
19.08	54.90	trace	0.070

In some places the ore is stained with malachite, suggesting the presence of copper ore in depth.

The magnetic iron ores of Ashe County, in the north-west of North Carolina, are described by Mr. H. B. C. Nitze.* The deposits lie mostly in the crystalline rocks, and, at present, are mostly undeveloped, owing to their inaccessibility. Some fifty years ago, a number of Catalan forges in this district produced tough iron of good quality. The ores are principally magnetites suitable for the manufacture of Bessemer pig iron, but some brown hæmatites and red specular ores are also found. The deposits may be grouped into three districts—the Ballou or River belt, the Red Hill or Poison Branch belt, and the Titaniferous belt. Analyses of ores from several localities in the first-named and most easterly belt show—

Silica . . .	27.59	2.40	5.73	20.79	...	17.88	16.68
Iron . . .	53.99	67.35	60.48	45.50	49.06	50.68	47.22
Sulphur . . .	0.055	...	0.003	0.002	...	trace	0.063
Phosphorus . . .	0.063	0.028	trace	0.024	0.018	trace	trace

A still larger number of analyses of ores from the second ore belt are given, and of these the following are a selection :—

Silica . . .	21.11	11.075	29.991	19.83	41.13	23.23	3.20	6.09
Iron . . .	43.17	58.930	36.350	51.55	23.39	44.87	65.40	47.45
Manganese . . .	4.62	...	...	...	...	...	2.58	9.102
Sulphur . . .	0.048	0.068	0.038	0.137	1.67	0.036	...	...
Phosphorus . . .	0.006	0.033	0.022	0.042	0.109	0.053	0.011	0.102

In the last of the three belts the ores were as follows :—

Silica	4.35	5.37	5.07
Iron	52.85	51.75	52.45
Phosphorus	0.013	0.018	0.022
Titanic acid	8.80	9.17	9.11

As a rule the deposits are lenticular, with a strike trending generally north-east and south-west. A map is given to show the distribution, and details are given of the deposits, from which the above analyses are taken. The ores are low in sulphur, and below the Bessemer limit for phosphorus. Although they are high in silica, they could pro-

* *Transactions of the American Institute of Mining Engineers* (advance proof).

bably be concentrated in magnetic separators. The titaniferous belt is the most persistent and shows the largest quantity of ore.

Iron Ore in Texas.—Mr. S. D. Mills* states that the total cost of iron ore mining at New Birmingham is less than two shillings per statute ton. Much of the area of this portion of the State, he adds, is covered by a blanket deposit of ore, a thin bed, that is, from 2 feet to 3 feet 6 inches in thickness, and covered with but a layer of some 6 feet of surface soil. Much of this ore can be mined and delivered to the furnace at considerably less than the sum mentioned above. It is a brown hæmatite, comparatively free from phosphorus, and in many places it assumes the dense form, breaking with a sharp conchoidal fracture. The ore gives a furnace yield of about 45 per cent. of iron.

The Iron Ore Mines of Virginia.—Mr. E. C. Pechin† gives a list of active iron ore mines adjacent to the Norfolk and Western Railway. In each case the ore is brown iron ore, and the author divides the mines into those yielding (1) mountain ore, (2) limestone ore, and (3) gossan ore. The author considers the sources of supply of ore of the various blast furnaces erected in this locality. Large quantities of brown iron ore are shown by extensive developments to exist in and on the limestones forming the valley at the foot of East River Mountain, through which the Bluestone River flows. This deposit has hitherto not been available, being three miles from a line of railway, but a branch line is about to be built.

New mines are being opened up in the limestone ore of Foster Falls. Here numerous test-pits and shafts have been made in over a mile of ground, and these have proved the existence of a good supply of ore. Another large, and at present wholly unproductive, iron ore district is being opened up by the Cripple Creek extension of the Norfolk and Western Railway. For fourteen miles this branch line passes through ore-bearing country. The author also refers to a number of other deposits, some of which are being worked, while the majority are still untouched.

Mr. J. L. Peyton‡ states that at the mine-bank near Vesuvius the supply of ore belonging to the Virginia Company is extremely large, 2,800,000 tons being actually in sight. The ore is a brown hæmatite;

* *Iron Age*, vol. xlviii. p. 743.

† *The Iron Belt* through *Iron Age*, vol. xlviii. p. 1031.

‡ *Iron Age*, vol. xlviii. p. 1079.

it is of excellent quality, and can be cheaply mined. Manganese ore and coal exist in the neighbourhood.

The Great Gossan Lode of Virginia.—Mr. E. C. Moxham * describes this enormous deposit of iron ore. It is a fissure vein lying between distinctly defined walls, with a pitch of about 45° to the south-west. The country is soapstone, micaceous and talcose slate, &c. The lode has been traced by its surface outcrop for 23 or 24 miles through Carroll County into Grayson County. The lode is really one of iron pyrites with a little copper, the upper portion of which has been decomposed, and now exists in the form of a brown iron ore—"gossan" ore. The line of demarcation between the iron ore and the pyrites is quite sharp and distinct, the former serving as a hard and excellent floor to the brown ore. It is of interest to note that analysis shows but little difference between the gossan ore taken from the immediate neighbourhood of the pyrites and that from the surface portions of the deposit. Between the pyrites and the iron ore cap a thin bed of copper ore has been extensively worked. The gossan ore varies in width from 12 to 40 feet at the surface, and from 40 to 70 feet at the contact with the pyrites. In depth the ore varies from 40 to 175 feet. In places the deposit assumes very large proportions. Thus at Cranberry the ore is 100 to 160 feet wide, and it is 140 feet deep, and in others the width is so considerable that the deposit assumes the nature of a thin bed or "blanket." The following is a fair average analysis of the ore sold :—

Fe.	SiO ₂ .	Mn.	P.	Cu.
41.28	9.74	0.31	0.064	0.29

The percentage of sulphur is usually high.

Phosphorus in Iron Ore.—The occurrence and distribution of phosphorus is one of the most important questions with which the steelmaker has to deal. Ever since 1781, when Meyer ascribed cold-shortness to the presence of phosphorus, knowledge of the effect of the total amount of phosphorus on iron and steel has been accumulating, but very little is yet known as to the effect of the condition of the phosphorus. The state of combination in which this element exists may influence its action quite as much as the total quantity present. It is highly probable that, in the majority of ores, phosphorus exists as a phosphate, but no regard is paid to the base or bases with which it may be combined.

* *American Manufacturer*, vol. I. p. 18.

Thinking that a study of the natural compounds containing phosphorus in the shape of phosphoric acid might lead to some interesting conclusions, Dr. W. B. Phillips* has drawn up a list of 141 minerals containing 1 per cent. and more of phosphoric acid. The list includes also the composition and crystal character of each mineral.

Association of Apatite with Beds of Magnetite.—The frequent association of apatite in layers in the midst of magnetic iron ore, according to Mr. W. P. Blake,† is significant of a stratified and organic origin of both minerals. The phosphate is usually more abundant towards the sides of the bed than at the centre, where the iron ore may be free from phosphorus, and near the planes of contact of the ore with the country rock apatite may abound. Several instances in which this is the case are given by the author. The Sanford ore bed in Northern New York carries large quantities of apatite in thin layers apparently interstratified or the result of segregation. This mineral, known locally as red sand, is most abundant toward the confines of the bed. Crystalline apatite may also be found in the outer layers of the bed of ore at Iron Mountain, and similarly in some of the beds of magnetite in Southern Utah.

Peculiar Variety of Spherosiderite.—A note on a peculiar variety of spherosiderite, a carbonate of iron, from South Hill, Campsie, is given by Mr. J. Young.‡ This ironstone is found in connection with the strata underlying the lower coal and limestone of the Campsie district, and forms a thin band made up of an aggregation of more or less rounded spherules, averaging one-sixteenth of an inch in diameter. In section these spherules show layers of carbonate of iron round a spherical centre in various shades of brown, and also a radiating crystalline structure. This form does not appear to have been noticed elsewhere in Scotland. A thermal action is probably the cause of this structure.

Magnetic Properties of Magnetite.—According to some investigations of Holz, magnetite can obtain a permanent magnetisation one and a half times that attained by steel even in strong fields. Some ex-

* *Transactions of the American Institute of Mining Engineers*, Baltimore meeting (advance proof).

† *Ibid.*

‡ Paper read before the Geological Society of Glasgow, February 11, 1892.

periments on this matter have recently been made by Anton Abt * with two samples of magnetite from Moravicza in Hungary. One piece was pure but somewhat porous; the other was dense, fine grained, and traversed by veins of chalcopyrite and malachite. Two parallelopipeds were cut and compared magnetically with similar-sized pieces of tempered steel reheated to blue. Holz's results were generally confirmed. The permanent magnetisation of magnetite was found to be greater than that of steel, but the temporary magnetisation and retentivity in face of a demagnetising force were less.

A Peculiar Form of Native Iron.—An account is given by Mr. G. C. Hoffmann † of a peculiar form of metallic iron found in Huronian quartzite on the north shore of St. Joseph Island, Lake Huron, Ontario. In what appeared to be fissure surfaces in the quartzite there were found thin layers of limonite, through which were disseminated metallic grains, generally of spherical form, and varying in size from 0·37 millimeter in diameter downwards. This layer had an oolitic structure, and contained 58·85 per cent. of the metallic spherules, which were separable by a magnet, 39·73 per cent. of limonite and 1·42 per cent. of siliceous matter. The metallic portion was soluble in hydrochloric acid, with a phosphoretted odour and a residuum of non-metallic nuclei amounting to 9·76 per cent. The metallic part showed on analysis—

Iron.	Manganese.	Nickel.	Cobalt.	Copper.	Sulphur.	Phosphorus.	Carbon.	Total.
97·79	0·57	0·11	0·23	0·10	0·13	1·07	?	100·00

The non-metallic nuclei consisted of more or less spherical grains, apparently coated with a humus-like substance, and gave on analysis—

Silica.	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Loss.	Total.
93·95	1·13	1·02	0·62	0·31	2·97	100·00

The description is accompanied by a coloured plate showing the original layer, the metallic spherules, and the nuclei.

Recent Researches on Meteorites.—In the Harvard collection of meteorites there is a small specimen of a pallas iron, which is highly prized as having the oldest authentic record. It was found in 1883, on the altar of a pre-historic mound in Ohio. Ever since the acquisition of this prehistoric specimen, specialists have endeavoured to identify the main mass from which it must have come. Recently some very

* *Wiedemann's Annalen der Physik und Chemie*, vol. xlv. pp. 80-90.

† *Transactions of the Royal Society of Canada*, 1890, vol. viii. section iii. pp. 39-42, one plate.

remarkable pallas irons have been found in Kiowa county, Kansas,* which have been claimed to be the original mass from which the prehistoric specimen came.

On a hasty examination the resemblance is very striking. On further study, however, Dr. O. W. Huntington † finds that the resemblance is not so remarkable as first appeared, whilst a comparison with the famous Siberian meteorite from Krasnojarsk, which has given the name of its finder, Pallas, to that class of meteorites, showed the two to be almost identical. On comparing the three pallasites, it is seen that all have dark olivine, strongly attracted by the magnet, appearing near the outside of the specimen, and frequently surrounding the clear green variety. All have a striking border of iron surrounding the olivine. All show signs of Widmanstätten figures in the ground-mass of the iron. The Krasnojarsk and the Kiowa meteorites have a large quantity of troilite between the crystals of olivine, and also patches of schreibersite between the troilite and the iron. These two further show a much larger proportion of iron than the prehistoric specimen. The Kiowa iron shows a far more perfect crystallisation than any other pallasite hitherto described. It also contains large quantities of chromite distributed through it, but no chromite is to be found in the prehistoric nor in the pallas meteorite.

Messrs. Cohen and Weinschenk ‡ find that the Toluca meteoric iron consists of: nickel iron, 95·05 per cent., tænite, 2·45 per cent., schreibersite, 1·17 per cent., and irregular particles 0·98 per cent. There was an insoluble residue. The tænite contains—

Fe.	Ni.	Co.	Cu.
65·17	34·29	0·40	0·14

The iron-nickel phosphide occurring in this meteorite exists as schreibersite and rhabdite. The former has the composition—

P.	Fe.	Ni.	Co.
15·38	63·97	19·15	1·68

Another phosphide in the metal contains—

P.	Fe.	Ni.
15·01	57·11	28·35

The irregular pieces occurring in the mass of the metal were found to consist of—

C.	Fe.	Ni+Co.
0·24	93·28	6·48

* *Journal of the Iron and Steel Institute*, 1891, No. I., p. 262.

† *Proceedings of the American Academy of Arts and Sciences*, vol. xxvi. pp. 1-12, with three plates.

‡ *Annales des k.k. Hofmuseums zu Wien*, 1892, p. 131.

Some quartz was observed in the insoluble residue and the newly observed mineral cliftonite, which the authors consider a pseudomorph after graphite or diamond. Chromite, graphite, pyroxene, augite, and other substances were also detected.

According to Mr. A. E. Foote,* in 1891 a meteorite was found near Cañon Diablo in Arizona, and was thought to form part of a vein of metallic iron. The largest mass discovered weighs 201 lbs., and has a somewhat flattened rectangular shape, showing deep pits, three of which pass entirely through the iron. One other large mass was found weighing 154 lbs. A mass weighing 40 lbs. was broken in pieces with a trip-hammer, and it was in cutting one of the fragments of this mass that diamonds were discovered. The diamonds are black and white, their nature being established by their hardness and indifference to chemical agents. Carbon in the form of a pulverulent iron carbide occurs in the same cavity with the diamonds. The proportion of nickel in the general mass is 3 per cent.

The Tonganoxie meteorite, described by Mr. E. H. S. Bailey,† was found in 1886 near Tonganoxie, Leavenworth county, Kansas. The specimen originally weighed 26 lbs. Its shape is that of an irregular triangular pyramid, $9\frac{1}{2}$ inches long, $6\frac{1}{2}$ inches wide, and $4\frac{1}{2}$ inches deep. The specific gravity is 7.45. As shown by a photograph accompanying the author's paper, the surface of the meteorite is covered with numerous depressions. The entire exterior is covered with a reddish-black coating of iron oxide, with occasional drops of chloride of iron exuding after having been exposed to the air. The analysis of the meteorite gave the following results:—

Fa.	Ni.	Co.	P.	Cu.	Total.
91.18	7.93	0.39	0.10	trace	99.60

On treatment with nitric acid the surface exhibited the Widmanstättian figures very perfectly.

The Welland siderolite was described by Mr. E. F. Howell.‡ Its analysis gave 91.17 per cent. of iron and 8.54 per cent. of nickel. It is singularly free from troilite and schreibersite, and thus offered Mr. J. M. Davidson§ a good opportunity for the analysis of its separated nickel-iron alloys. Between the decomposed outside and the compact centre there was a zone in which the oxidation was superficial and confined to the planes of contact of the different alloys that form the

* *American Journal of Science*, vol. xlii. pp. 413-417.

† *Ibid.*, vol. xlii. pp. 385-387.

‡ *Proceedings of the Rochester Academy of Science*, 1890, pp. 86-87.

§ *American Journal of Science*, vol. xlii. pp. 64-66.

Widmanstätten figures. It thus became possible to separate the kamacite and tænite in quantities sufficient for analysis. It was intended to analyse the plessite as a whole; but on examination its fine layers were so suggestive of kamacite and of tænite that an attempt was made to analyse them separately. The analytical results were as follows, the analyses of kamacite and tænite being given each next to its corresponding part of the plessite:—

	Kamacite.	Plessite.		Tænite.
		Kamacite-like Part.	Tænite-like Part.	
Fe	93.09	92.81	72.98	74.78
Ni	6.69	6.97	25.87	24.32
Co	0.25	0.19	0.83	0.33
C	0.02	0.19	0.91	0.50
Total . . .	100.05	100.16	100.59	99.93

The physical and chemical correspondences appear to justify the conclusion that in the Welland meteoric iron there are but two distinct nickel-iron alloys, kamacite and tænite, and that the so-called plessite consists merely of thin alternating lamellæ of these two alloys. It is unsafe to generalise on a single analysis; but an examination of the markings of other meteoric irons suggests the thought that in them also there may be but two distinct alloys.

According to a manuscript recently discovered by G. Stefanescu* in the library of the Roumanian Academy, a meteoric iron fell in 1774 at Tirgoviste, in Roumania. The meteorite appears to have been of the ordinary character, and the fall was accompanied by the usual phenomena.

Manganese Ore in Cuba.—Mr. E. J. Chibas† states that the chief manganese ore deposits of Cuba are situated in the province of Santiago de Cuba. Here a range of mountains, the highest peak of which is 7670 feet above the sea-level, skirts the Cuban coast. This range becomes broken into a number of smaller and lower mountain ranges, at the summits or on the flanks of which the manganese deposits are usually found. The chief ores are a light crystalline variety

* *Comptes Rendus de l'Académie des Sciences*, vol. cxii. p. 450.

† *The Polytechnic*, through *Iron Age*, vol. xlix. p. 200.

of pyrolusite and psilomelane. Considerable quantities of wad are also found. The ores generally occur in association with red or yellow jasper, which seems to have been greatly disturbed, and often dips at steep angles. Sometimes the ore deposits are wholly in this rock, while at other times they exist in the form of pockets, or of deposits irregularly distributed over many acres of clay, representing the result of the decomposition of the ore-bearing rock. This clay assumes various colours, from red, through purple and yellow, to white or brown, according to the states of hydration and oxidation of the iron and manganese the clays contain. These pockets or deposits are usually covered by about a foot of soil, and their number or extent is therefore unknown. Sometimes they contain several hundreds of tons of solid ore, while at other times they are smaller and greatly mixed up with jasper.

The average percentage of manganese in the cargoes of this ore shipped from Cuba is between 47 and 53, with 4 to 9 per cent. of silica and 0·03 to 0·10 per cent. of phosphorus; one cargo from the Gloria mine assaying as much as 55·21 per cent. of manganese. The most extensive ore deposits are those forming the Ponupo group, at a distance of 12 miles from the railway station of Cristo. Here, with pick and shovel, a man can extract between three and four tons of ore a day. The ore is then placed in bags containing each about 100 lbs., and carried to the railway station either on mules or in carts. The cost of the ton of ore delivered at Philadelphia is approximately as follows:—

	Dollars.
Mining	1·50
Placing in bags	1·50
Transport to railway	5·00
Transport to Philadelphia	6·00
Total	14·00

This is in Cuban currency, and is at the rate of 12·60 dollars United States coin.

Formation of Manganese Ore Deposits by Lateral Secretion.—Professor F. von Sandberger* has examined samples from the Sacra Familia mine, in Costa Rica. These samples were both from the lode itself, and from the adjacent country—a quartzose augite andesite. The lode is remarkable from the frequent occurrence of manganese ores, and these the author attributes to the manganese of the augite.

* *Sitzungsberichte der Königlichen bayerischen Akademie der Wissenschaften*, 1891, p. 191.

All the minerals in the vein-stuff were found in the country rock. The manganese ores found at Nagyág, Felsóbánya, and Nagybánya in Hungary are derived probably from the manganese contents of hornblende.

II.—IRON ORE MINING.

Iron Ore Mining at Danville, Pennsylvania.—Some notes on the iron ores of Danville, Montour county, Pennsylvania, are given by Mr. H. H. Stock,* together with a description of the long-wall method of mining used in working them. The Montour ridge is an anticlinal fold, about twenty-seven miles long by three-quarters of a mile broad. It is cut through by a creek near Danville, where the ores have been worked from the outcrop on the southern slope. A section and map of the ridge are given showing beds of ore. Two varieties of ore exist, the limestone or Danville fossil ore, and the sandstone or block ore. The fossil ore is fossiliferous limestone impregnated with iron, with two partings, and both roof and floor of a slaty rock. The richest ore is found in the middle split, and is 15 to 20 inches thick, and it changes from soft to hard ore without apparent reason. The block ore is rich near the outcrop, and the bed has an average thickness of 18 to 24 inches. Below this deposit, and 150 feet above the contact of the Clinton and Medina measures, is found the birdseye ore. The first two of the following analyses are of soft fossil ore, the next two of hard fossil ore, and the last one of birdseye ore from Snyder county:—

H ₂ O.	SiO ₂ .	Fe ₂ O ₃ .	Al ₂ O ₃ .	CaO.	MgO.	S.	P.	MnO.	CO ₂ .
3.50	19.28	67.30	7.94	0.86	0.80	0.02	0.47	...	...
7.05	24.11	60.49	2.45	1.12	0.43	0.02	0.70	3.20	...
...	5.56	38.81	4.34	25.17	2.85	0.10	0.23	...	23.66
0.18	6.04	28.65	6.95	29.44	2.17	0.60	0.15	...	24.66
...	11.38	67.81	2.09	12.64	4.02	0.16	0.41	1.30	...

The history of the various mining operations in this field is given with sketch maps to show the approximate extent of the workings. The long-wall method was introduced to work these beds, which are from 4 to 5 feet thick at the breasts. Levels are driven 90 feet apart, each face being kept in advance of the higher roads. These gangways are 7 to 10 feet wide, and 5½ to 7 feet high. The upper levels are bounded on their lower side by the stowing, and the floor is taken up

* *Transactions of the American Institute of Mining Engineers* (advance proof),

to make them a sufficient height and to facilitate loading the ore from the shoots into the waggons. Breasts are turned off at 35° to 45° with the gangway, and are usually two feet wide by 24 to 30 feet long. Usually there are five breasts between each level, and the ore is taken out of all three splits, or the middle one only, according to their richness. The waste is used for stowing, and the shoot to each breast is carefully walled, and sometimes boarded. Timbering is used in the soft ore, and the ventilation is natural. The waggons are loaded from the shoots, and run along the level to a turntable on a movable bridge over the incline up which they are hauled. Figures are given to show the cost of mining.

Sinking Shafts in Saxony.—The official report * on the sinking of two shafts in Saxony enables a comparison of the results to be made. The first, the Neujahr shaft, was sunk by means of rock-drills (Schramm-Mahler No. 2 system) with compressed-air hoisting, whilst the second, the Türk shaft, was sunk by hand-boring with windlass. The miners in the Türk shaft were, however, able to use the cage to a certain depth, and were obliged to climb by the ladder for a distance of only 115 feet, whilst their fellow-workmen at the Neujahr shaft were obliged to climb by the ladder the whole way, a distance of 360 yards. Both shafts were inclined. In the Neujahr shaft there was no difficulty with water; but in the Türk shaft a Körtling steam-pump was used. The rock in the former case consisted of clay slate and quartz, and in the latter of clay slate and hard mica diorite. The following were the results obtained :—

Description.	Türk Shaft, Hand-boring and Windlass.	Neujahr Shaft, Rock Drills and Compressed Air Hoist.
Depth sunk	78 feet 9 inches	82 feet 3 inches
Dimensions of shaft	18 feet by 6 feet	15 feet by 5 feet
Volume excavated	8327 cubic feet	5898 cubic feet
Average contract price per metre depth	£10, 12s. 11d.	£6, 15s. 3d.
Number of shifts	1680·5	891·0
Cost of wages	£213, 16s.	£127, 15s.
Cost of dynamite	£42, 15s.	£43, 6s.
Total cost	£256, 11s.	£171, 1s.
Cost per cubic metre—		
Wages	17s. 11d.	14s. 4d.
Dynamite	3s. 7d.	5s. 2d.
Total	£1, 1s. 6d.	19s. 6d.

* *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1891, p. 136.

These results clearly show the great advantages to be derived from the use of rock drills and compressed air hoists in shaft-sinking.

Sinking through Wet Gravel and Quicksand.—An account is given by Mr. W. Kelly * of the process of sinking a shaft through 60 feet of glacial drift to explore an ore body near Norway, Michigan. A large feeder of water had been found at a depth of 20 feet. The top of the shaft was to be 6 by 13 feet, so the sinking caisson was built 4 feet larger each way at the bottom to afford room for the pump and the working. Two 40-horse-power boilers, a winding engine, a derrick, and two pumps rated at 400 gallons per minute were put up at first. Later on two other boilers of 35 and 100 horse-power and two other pumps were also employed. The caisson was built up of timbering and divided into three compartments, the side ones being loaded with sand to increase the weight. The timbering was built up as high as the derrick would permit, and was allowed to sink as the ground was extracted inside. After sinking 27 feet, the second two pumps had to be put in, as much as 1500 gallons per minute being raised at one period. The work went on well until the hard pan was struck at a depth of 60 feet, when the lining sank somewhat irregularly, and had to be supported by props and the loading increased. The pan was 14 feet thick and the lining was carried through it and 2 feet into the solid slate. The total time employed in these operations was sixty-three days.

- To keep out the water, the shaft was sunk 11 feet farther into the rock, and a set of timber 6 by 13 feet inside, of 12-inch square timber, was placed in line with the top set in the shaft and carefully wedged tight. Six sets of the same size were placed on the first, and bolted together so as to be level with the bottom of the shoe. The space behind these timbers was filled with concrete on which gravel was laid, to afford a free passage for the water to twenty 2-inch holes bored through the top set. On this latter set, three sets of increasing size were placed, so that the top set was against and bolted to the caisson. The space between these sets was also filled in with concrete. These operations took eighteen days. The holes in the perforated set were then plugged and the interior of the shaft caulked. The water then fell to 90 gallons per minute. The total time thus far was five months, of which four weeks were lost time that might have been

* *Transactions of the American Institute of Mining Engineers* (advance proof).

saved. The shaft was then 84 feet deep and ready for sinking in the ordinary way.

Breakage of Winding Ropes in Saxon Mines.—C. Menzel * states that since 1884 the law has been enforced in Saxony that all breakages of winding ropes and chains shall be notified to the mine inspectors. The returns obtained in this way show that during the seven years ending in 1891 there were in all 133 breakages of ropes and chains in the Saxon mines. Of this total, 32 occurred in metal-liferous mines, 97 in collieries, and 4 in lignite mines. The breakages during the various years were as follows :—

Year.	Metal Mines.	Collieries.	Lignite Mines.	Total.
1884	4	23	1	28
1885	2	20	1	23
1886	1	24	...	25
1887	3	12	1	16
1888	6	6	1	13
1889	9	8	...	17
1890	7	4	...	11

From these figures it is seen that, in the case of the collieries, although the output increased $5\frac{1}{2}$ per cent. from 1884 to 1888, and then decreased, the number of breakages is considerably less, whilst the depth of the shafts has continuously increased. The majority of breakages, as would naturally be expected, occurred as the cage was being raised; in only 18 cases the breakage occurred as the cage was being lowered. The causes of the accidents cannot be ascertained with accuracy. Some 43 of the cases were, however, undoubtedly due to bad or worn material; 5 to 7 were due to imperfect welding, 20 to friction on the pulleys, and 20 to the jamming of the cage or kibble in the shaft.

The question whether it is desirable to have safety-catches or merely to trust to the rope being of good quality is not yet definitely decided by the mine managers. In the 79 cases in the collieries in which safety-catches were provided, they came into satisfactory action in 60 cases, or, in other words, 76 times in 100. These results certainly appear to be in favour of the adoption of safety-catches.

Steel Supports in Metal Mines.—Acting on the suggestion of Professor C. Le Neve Foster,† H.M. Inspector of Mines, the manager

* *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1891, pp. 39-81.

† *Reports of H.M. Inspectors of Mines for 1891*.

of the Foxdale Mine in the Isle of Man decided to try the experiment of lining part of a level with steel supports instead of the usual sets of timber. Some of the frames were put up in the 230-fathom level in July 1890, and have given great satisfaction. Adjacent sets made of Irish larch and of Norway timber, which were put in at the same time, have already become so crushed and broken as to be practically useless. The steel frames, on the other hand, are practically as good as they were originally, and are likely to last for many years. In spite of the expense of sending these steel frames from the north of France to the Isle of Man, they cost only twice as much as the timber frames, and, as they will evidently last more than twice as long, they are undoubtedly superior on the score of economy, to say nothing of many other advantages.

Driving Levels in Hard Dolomite.—A level has been driven by hand in very hard dolomite in the Raibl mining district of Carinthia. V. Walzl* gives details regarding the running of this drift. During eleven months 777½ eight-hour shifts were worked off, 2411 bore-holes were drilled, 2701 drills were used; 344 lbs. of No. 1 dynamite, 107 coils of fuse, and 2442 detonators were exploded, and 174 lbs. of linseed oil was also used. The holes were drilled, as a rule, to a depth of 17·7 inches. The drift itself was 7 feet 2 inches high, and 4 feet 7 inches broad. During the period above referred to it was driven 155 feet at a total cost of £90.

Rock Drills.—Some illustrations have been published† of the most recent forms of the Sullivan diamond drill for prospecting or other work. A friction clutch is introduced between the feed gear and the tool to prevent danger to the diamond.

An illustration is given‡ of the Priestman oil engine adapted to a rotary drill of the Steavenson type. Rope gearing is used between the drill and the engine. The machine weighs 50 cwt., and will drill over a surface 14 by 10 feet.

Electric Percussion Drills.—According to Mr. A. T. Snell,§ the fact that workshop tests of electric percussive drills have not been realised in practice is due to two reasons. The work and the treat-

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 563.

† *Industries*, vol. xii. p. 139; *Engineering and Mining Journal*, vol. liii. p. 209.

‡ *Iron*, vol. xxxviii. pp. 533, 535.

§ *The Electrician*, vol. xxviii. pp. 683, 684.

ment the drills receive is very rough, and there are the difficulties connected with ventilation owing to the heating of the drill and the absence of a supply of fresh air, which is introduced with ordinary air-driven drills. This latter difficulty in many cases may make electric drills impracticable, cost in confined workings being subordinated to other considerations. Even in open workings, however, these drills have not had much success, and the reason is to be found in the drill itself. Reciprocating electric devices are not efficient, as solenoidal action is the least effective way of converting electric energy. The simplest form of drill consists of two solenoids alternately acting on a plunger, but the difficulty from sparking is great. For this the author tried oil insulation without success. An improvement consists in the use of a single solenoid drawing back the drill against a spring, and this form might have done useful work if the sparking difficulty could have been overcome. All these direct acting drills are primarily designed to be used on electric lighting circuits. A distinct advance on these methods is made with pulsating or alternating currents, or with a combination of the two. Unfortunately specially arranged circuits with three or more wires are required, though these wires could all be laid in the same cable. No switches are required, however, as the circuits are never opened while running. The simplest drill of this class is one coupled to a di-phase current alternator, in which the two coils are successively energised. In this form the two strokes are made at the same rate, but the back-stroke can be diminished in energy by altering the coils, although at a loss. The Marvin drill * is an instance of the double solenoid type. An elaborate series of experiments, made by Mr. W. S. Aldrich,† on the variable action of two coil solenoids are referred to by the author. When the coils are in opposition, as in the Marvin drill, the blows given are greater, and the impact more sudden, such as are required; but the heating of the core is greater than when the coils are wound to magnetise the core always in the same direction. To lessen the force of the in-stroke a resistance may be introduced, or one coil may be wound in sections which are coupled in parallel at the end of the stroke. The latter, however, requires a switch and is too complicated.

Theoretically, the best results are attained by a combination of pulsating and alternating currents, as used in the Van Depoele drill.‡

* *Journal of the Iron and Steel Institute*, 1891, No. II. p. 156.

† *Journal of the Franklin Institute*, vol. cxxxiii. pp. 317-328.

‡ *Journal of the Iron and Steel Institute*, 1891, No. II. p. 157.

In this drill the in-stroke can be made as light and the out-stroke as heavy as desired by the use of the three coils, only three supply mains and no switch being required. The author is not aware if this drill heats much, but as the magnetic induction varies within wide limits, although it is always in the same direction, the conditions indicate that it does. The iron circuit of a reciprocating drill ought to be thoroughly laminated to avoid loss by eddy currents and hysteresis, but this is not easily reconcilable with mechanical and commercial considerations. The dynamos also have to be specially constructed. Considerable improvements will have to be made before these drills are widely used.

In some notes on electro-magnetic machinery by Mr. W. S. Aldrich,* the various forms in which solenoids may be adapted to electric percussive drills are considered, and an account is given of the Van Depoele drill. The various forms considered are the single-coil pulsating current solenoid, the two-coil pulsating current solenoid, and multiple-coil pulsating current solenoid, also the three-coil pulsating and alternating current solenoid.

Several installations of electric percussive drills have been made in mines during the past year,† but have not met with the success expected. This appears to be chiefly due to the heating in the solenoids from the rapid alternations in the current, thus causing a great loss of mechanical energy. Most of the drills now in use depend on solenoids for their action, though all the rest of their gear is the same as in an ordinary percussive drill, only that the piston-rod and the rifle-bar have to be made of non-magnetic material, so as not to interfere with the magnetic field in the solenoids. Not only is power lost, but the heating is so intense as to make the drill objectionable in a small heading. Inventors are, however, endeavouring to cope with this problem.

The Shape of Bore-Holes for Blasting.—Mr. W. L. Saunders ‡ describes the Knox system of quarrying, in which the bore-holes for blasting are made of shapes other than round in section, so as to direct the explosive force along definite lines and to prevent shattering of the material. In one system that has been used, a cartridge of lens section placed in a round bore-hole has been used, the space between the sides of the cartridge and the bore-hole being filled with tamping

* *Journal of the Franklin Institute*, cxxxiii. pp. 130-145, 214-234.

† *Engineering and Mining Journal*, vol. lli. p. 730.

‡ *Transactions of the American Society of Civil Engineers*, vol. xxv. pp. 501-518.

material. In another method several bore-holes were drilled close together, and the intervening spaces broken down to form a long channel, which was charged with powder and tamped. By the Knox system the hole is made of lens section, so that the results mentioned above in the first system are obtained. This form of hole is obtained by using a suitable reamer in a round hole. Hand labour is employed, as with machines it is difficult to get the reamer to make the angles of the hole truly in line. In some instances a hole of somewhat square section may be made by the same process, so as to make two sets of cleavage at right angles with each other.

Extinguishing a Fire in Lake Superior Mine.—During the last eight years Mr. J. P. Channing* has seen nine mine fires in the Lake Superior region. The most recent of these was at the Lake Superior mine at Ishpeming, Michigan. This mine is in a body of soft hæmatite ore which is worked by drifts, from which chambers are driven north and south every eighteen feet, so as to leave pillars eighteen feet wide. There are two shafts, of which the winding-shaft is over 500 feet deep, and is divided into two compartments, one for winding, the other for the balance, ladders, and pipes. Fire was noticed on November 28, 1891, and in five hours the men were all out and the shafts were stopped with planks, manure, and moist sand. A two-inch pipe was then lowered in the burning shaft to a depth of 190 feet and the steam from a 60 by 18 inch return tubular boiler at 40 lbs. pressure was turned into it. The pipe was then lengthened to 350 feet and steam allowed to play into the shaft for sixty hours; and after about a week the coverings were removed from the shaft and the fire found to be extinguished. Owing to the prompt and effectual means taken, the damage was not found to be very considerable.

Filling of Mines.—Mr. E. Everett,† of the Ludington mine, Iron Mountain, is about to experiment in the direction of filling the mine, using a steel tubing through which the dirt will be run from the surface to the bottom of the mine. This tubing will be 3 feet in diameter, and will be composed of $\frac{3}{8}$ -inch plates. From the surface to the bottom of the mine the distance is 1500 feet. This pipe will be filled, and the filling taken from the bottom as it is needed. There has been some discussion as to whether the filling would become so firmly packed in

* *Engineering and Mining Journal*, vol. liii. p. 106.

† *The Colliery Guardian*, vol. lxii. p. 1029.

the tube that it would not run. The pressure will be great, no doubt, but the material is mostly dry sand, and ought to move freely. Provision will be made to prevent serious loss of time in case the material should become fast by supplying the pipe with several openings. The pipe will occupy one of the four compartments of the shaft. The shaft is vertical, which is in favour of the plan.

The Cost of Mining Iron Ore in the United States.—Mr. Carroll D. Wright,* in his official report on this question, gives the following statement as to the cost of mining iron ore in the United States, together with partial analyses of the ores mined :—

THE COST OF MINING ORE.

	Kind of Ore.	Iron.	Phos- phorus.	Iron Ore mined. Statute Tons.	Total Cost.
					\$
1 {	Red, hard, fossiliferous	35.46	(a) {	93,055	0.641
2 {	Red, soft, fossiliferous	47.78	(a) {		
3	Red fossiliferous	46.00	0.16	19,066	0.498
2	Brown hæmatite	50.00	0.05	33,000	0.574
4	Red hæmatite	50.98	(a)	89,826	0.611
5 {	Red hæmatite, hard	38.28	(a) {	138,055	0.605
5 {	Red hæmatite, soft	51.18	(a) {		
6	Red hæmatite	(a)	(a)	63,788	1.228
7	Brown hæmatite	51.31	(a)	32,226	0.913
11	Magnetite	65.60	0.114	52,713	1.915
12	Hæmatite	64.50	0.030	69,030	1.412
13	Hæmatite	63.00	0.045	73,506	1.085
15	Hæmatite	61.00	0.085	35,200	1.606
17	Hæmatite	58.00	0.045	32,600	1.462
18	Specular	62.70	0.109	114,579	1.696
19	Red hæmatite	61.00	0.055	74,000	1.521
20	Magnetite and specular	63.33	0.040	215,098	2.512
21	Hæmatite	63.29	0.045	771,279	1.249
22 {	Red specular, hard	63.00	0.068 {	323,342	1.739
22 {	Hæmatite, soft	60.50	0.089 {		
24	Red hæmatite	60.00	0.055	29,736	2.235
25	Specular	65.00	0.050	20,033	2.630
26	Hæmatite	58.61	0.592	185,434	1.258
27	Hæmatite	58.80	0.188	50,200	1.505
28	Hæmatite	60.60	0.344	159,538	1.094
29	Hæmatite	62.85	0.054	550,972	1.718
30	Blue hæmatite	65.00	0.027	21,500	2.038

(a) Not reported.

* *Iron Age*, vol. xlviii. p. 925.

THE COST OF MINING ORE (*Continued*).

	Kind of Ore.	Iron.	Phos- phorus.	Iron Ore mined.	Total Cost.
				Statute Tons.	
					8
31	Hæmatite, non-Bessemer	66-00	0-090	6116,000	1-903
	Hæmatite, Bessemer	67-00	0-010		
	Specular, No. 1	67-60	0-042		
32	Specular, No. 2	63-52	0-055	287,390	1-921
	Magnetite	69-77	0-051		
33	Red specular, Bessemer	65-00	0-045	c140,440	1-974
	Red specular, non-Bessemer	62-00	0-065		
	Specular, slate	62-66	0-150		
34	Hæmatite	61-00	0-068	244,060	2-319
35	Hæmatite	52-18	0-642		
36	Red hæmatite	62-33	0-120	18,980	0-919
37	Red hæmatite	62-60	0-112	26,221	1-825
38	Red hæmatite	63-80	0-100	53,315	1-269
	Red hæmatite	67-70	0-051	41,398	1-360
39	Red semi-specular hæmatite, Bessemer	67-43	0-100	d558,800	1-340
	Red semi-specular hæmatite, non-Bes- semer				
40	Hæmatite	65-00	0-040	317,827	1-253
41	Hæmatite and specular	59-70	0-086	45,440	1-032
42	Specular	65-00	0-026	117,403	1-853
43	Specular hæmatite	55-66	0-115	40,000	1-068
45	Fossiliferous hæmatite	42-52	0-750	78,549	1-345
46	Magnetite	64-50	0-050	145,215	6-829
58	Hæmatite	43-03	0-250	45,815	1-196
65	Fossiliferous, hard	34-56	0-375	29,958	1-154
	Fossiliferous, soft	47-14	0-480		
66	Hæmatite	30-00	0-400	123,574	1-161
67	Brown hæmatite	42-00	0-013	30,250	1-480
68	Brown hæmatite	48-09	0-482	63,500	1-283
69	Brown hæmatite	40-00	0-642	33,546	0-760
70	Brown hæmatite	42-00	0-003	49,460	1-462
71	Red hæmatite, Bessemer	62-00	0-036	51,554	3-075
72	Hæmatite	60-50	0-257	218,738	1-053

(b) Bessemer, 8800 tons, non-Bessemer, 107,200 tons.

(c) Bessemer, 65,000 tons; non-Bessemer, 75,440 tons.

(d) Bessemer, 298,314 tons; non-Bessemer, 260,486 tons.

No. 20, Champion mine; No. 21, the Norrie; No. 29, the Chapin; No. 31, the Ludington; No. 32, the Republic; No. 39, the Minnesota; and No. 49, the Chandler. All these are Lake Superior mines.

Basing his calculations on the details obtained in the case of 6,317,171 tons of ore, the author obtains the following average cost of mining of the statute ton of ore:—

Cost of Mining Iron Ore.

	Dollars.
Labour	1-039
Officials and clerks	0-049
Supplies and repairs	0-359
Taxes	0-035
Total	1-482

Including insurance, interest, depreciation of plant, and royalty, the cost at some of the larger mines was as follows:—

Mine.	Dollars.
Champion, ...	3'096
Norrie	1'667
Chapin	2'471
Ludington	2'483
Minnesota	1'902
Chandler	1'648

To this must be added the cost of haulage to the shipping port and the cost of shipment.

III.—MECHANICAL PREPARATION.

Sampling Iron Ore.—The taking of proper samples of crude ore seems to be less thoroughly understood or less carefully practised than its importance demands. Reports of very accurate assays and analyses are often encountered, the weight of which as evidence wholly depends on the method of obtaining the sample, and this is often of no value because there has been no proper sampling. With a view to constitute a record, Mr. W. Glenn* gives an account of the best method of sampling by hand, a method as old as Cornish copper-mining, taking as an example a 10-ton pile of 10 per cent. copper ore prepared for market. With regard to larger and rougher ore piles, it is not unusual for a sample to be required of a pile of 100 or 200 tons. Such piles are apt to consist of lumps larger than a man's head, together with masses of all smaller sizes. Where a pile is formed by tipping ore uniformly upon its top, the probability is that the pile is homogeneous. In such a case, it is safe to make short cuts into it at several points around its base, and to consider as sample the ore so obtained. It is safer to make one cut through the pile, retaining as sample each third shovelful. In forming ore-piles of the weights given, it is a good custom to put upon a separate platform each tenth or twentieth barrow-load coming from the mine; the small pile will prove a fairly good sample of the large one. But no matter how it may be obtained, the rough sample is to be broken and mixed and proceeded with after the regulation method.

Mr. E. K. Landis† gives the results of ten years' experience in the

* *Transactions of the American Institute of Mining Engineers*, Cleveland meeting (advance proof).

† *Ibid.*, Glen Summit meeting (advance proof).

sampling of iron ore by a method which seems simpler than that described by Mr. Glenn.

If a pile or truck-load of lump iron ore is to be sampled, each piece that can be reached over the entire surface is picked up, and a small fragment is broken off and kept, the size of the fragment being in proportion to that of the lump from which it is broken. When the entire surface has been gone over, the sample is reduced by crushing until it all passes a 10-mesh sieve. It is then thoroughly mixed on a large sheet of paper, and a small portion is taken with a large spatula from points all over the heap, and this is reduced in a mortar until it all passes a 20-mesh sieve. It is then again treated on the paper as before, and the resulting sample is passed through a 40-mesh sieve and bottled. This is subsequently mixed once more on a smaller paper, and a sufficient quantity for analysis is taken out and ground to the required fineness in an agate mortar.

When fine ore mixed with lump is to be sampled, the lump is sampled first as described. Then the fine is sampled by taking handfuls from all over the exposed surface, the quantity taken being such that the same ratio is observed between fine and lump in the sample as exists in the ore itself.

It is doubtless true that thorough hand-sampling gives as good average results as can be obtained, yet all hand-sampling is subject to the possible incompetency, carelessness, or dishonesty of the workmen employed. It is, moreover, tedious and expensive, and requires large space. For these and other reasons machine-sampling is regarded with more favour than ever before.

In an elaborate paper covering twenty-seven pages and illustrated by sixteen drawings, Mr. H. L. Bridgman* describes not only his mechanical ore samples, but a system he has devised which gives the machine its greatest effect by embracing all the sampling operations from the receipt of the material to the filling of the bottles. To this end the following appliances have been designed:—(1.) Size A. sampling machine. This gives double samples and three cuts on each sample. It is intended for original samples of any size, and gives final samples of 1 to 2 per cent. of the original weights. Its average capacity is 20 tons per hour. (2.) Size B. sampling machine. This gives a single sample and three cuts. It is intended for the smaller original samples and for work requiring only one sample, as, for

* *Transactions of the American Institute of Mining Engineers*, Glen Summit meeting (advance proof).

instance, iron ores and the various furnace products. It is also intended for cutting down the crushed final samples of the A. machine. Its average capacity is two to four tons per hour. (3.) Size C. sampling machine. This gives laboratory samples for all small work. (4.) Mixer and divider. This performs the final preparation and distribution of the assay samples.

Pulverising Magnetic Iron Ores at the Croton Mines.—By the aid of five illustrations, Mr. W. H. Hoffmann * describes the grinding-machine known as the Sturtevant mill, used for pulverising magnetic iron ores at the Croton mines, New York. The mills have been in use two years, and thus far the screen-holders show very little wear. The ore is conveyed through a hopper at the top of the case, and fills the cases and the revolving cylinders at each end of it. These cylinders being put in motion, hurl their contents against each other with such force that the ore is at once crushed. The author knows of no other machine that will pulverise as perfectly, as rapidly, and with as little wear and tear. With an expenditure of 96 horse-power, 24 tons per hour of well-roasted ore can be pulverised to 12-mesh in a 20-inch mill. In grinding to any degree of fineness, the grains are always in the form of cubes, thus assuring very satisfactory work in the subsequent separating process.

Magnetic Separation of Iron Ore.—In an exhaustive paper on the present condition of ore-dressing in Saxony, the Hartz, and Rhenish Prussia, M. Bellom,† gives a description of the magnetic treatment of the ores at Friedrichssegen in Rhenish Prussia. This treatment is applied to products whose specific gravities are so similar that it is impossible to have recourse to the ordinary processes of ore-dressing. This is the case with the zinc blende associated with spathic iron ore at Friedrichssegen.

The apparatus for magnetic separation are of two distinct types—one in which permanent magnets are employed, and the other in which electro-magnets are employed. Apparatus of the first class have the advantage of being less costly, but they have a smaller output. Thus, the Vavin separator cannot treat more than 440 lbs. per hour, whilst with the Friedrichssegen electro-magnetic apparatus, as much as 1000

* *Transactions of the American Institute of Mining Engineers*, Baltimore meeting (advance proof).

† *Annales des Mines*, 8th Series, vol. xx. pp. 5-186.

lbs. may be treated in the same time. The apparatus based on the application of electro-magnets are of two types. In one, as in the Sella separator, the current is interrupted from time to time so as to permit the attracted portions to fall; in the second class, the current is constant, and the fall of the attracted particles is effected by causing them to pass out of the magnetic field. This latter plan, which is obviously the less complicated, has been adopted at Friederichsseggen. The apparatus, the construction of which is described by the aid of two drawings, is composed of a brass cylinder moving around a fixed horizontal axis which carries four immovable electro-magnets. A Siemens dynamo of one horse-power is sufficient for four separators, each of which is able to treat per hour 1000 lbs. of a mixture of blende and ferrous oxide. The motion of the separator does not consume more than one-sixth horse-power. The dynamo furnishes a current of 17 ampères and makes 1000 revolutions per minute. The brass cylinder makes 45 revolutions. One workman is enough to attend to a group of four separators.

This separator possesses two great advantages: the electro-magnets being fixed and protected by the brass cylinder from the action of dust, rarely require repair, and the outturn is greater than that of similar machines, trials made at Przibram with an apparatus with interrupted current having given a maximum hourly outturn of only 300 lbs.

At Friederichsseggen the dressing-floor is divided into two sections, each of which, with eight separators, is able to treat in twelve hours 24 tons of calcined ore, yielding 7 tons of blende and 17 tons of iron ore. The crude material, containing 12 to 15 per cent. of zinc, 21 per cent. of iron, and 2 per cent. of lead, yields blende with 33 per cent. of zinc, 6 per cent. of iron, and 2 per cent. of lead, and iron ore with 38 per cent. of iron, 5 per cent. of zinc, 10 per cent. of manganese, and 2 per cent. of lead. The loss during calcination is 20 per cent.

Mr. N. M. Langdon * gives the results of two years' experience with the use of magnetic concentrates in the Port Henry blast furnaces, New York. In the early part of 1889 the supply of concentrates was irregular, but in March 1891 new concentrating plant for the ores was started. Bessemer and forge iron are made at these furnaces from the New Bed (Bessemer), Old Bed (high phosphorus), and Mill ores. The run of the mine is usually a lump ore, with up to as much

* *Transactions of the American Institute of Mining Engineers*, Glen Summit meeting (advance proof).

as half fine in the case of Old Bed ore. A start was made with $\frac{1}{14}$ of the charge, consisting of concentrates, and this was increased up to $\frac{3}{10}$ without any particular effects being noticed except the increase of iron due to the greater iron contents of the charge. When the new plant was put up, the charge of concentrates was increased to $\frac{4}{10}$, and the furnace began to get hotter, so the burden was increased. The proportion was further increased to $\frac{6}{10}$, but the furnace worked smoothly and regularly, but with 1 to $1\frac{1}{2}$ lbs. higher pressure of blast, and the average fuel per ton of iron was 18 per cent. lower than usual. Of this reduction in fuel about $5\frac{1}{2}$ per cent. was due to the increased yield of iron in the mixture. The iron was, however, about one grade lower, being less open. After running a short time on forge iron, the furnace was changed to Bessemer, using New Bed concentrates, 10 mesh, 67 per cent. of iron, as follows:— $\frac{4}{10}$, ten days; $\frac{6}{10}$, four days; $\frac{8}{10}$, fourteen days; and $\frac{7}{10}$, eleven days. The furnace worked well and behaved as above. With proper management it seems, therefore, that there is no difficulty in using 80 per cent. of concentrates, and that there is an economy in fuel, which may be ascribed to the comminution of the ore.

Mr. E. K. Landis* directs attention to the distribution of the iron in the tailings from magnetic concentration. Some ores are so intimately mixed with their gangue that a large loss of iron in the tails is unavoidable. In many cases the gangue contains minerals carrying iron as silicate or otherwise combined, and this iron a magnetic machine cannot extract. It is obviously unfair to charge the machine with this loss of iron, and consequently a satisfactory test of any such apparatus would require that the iron present in the ore as magnetite should be determined, and the proportion of such iron in the tailings should be the measure of the loss as compared with the efficiency.

At the Croton mines the magnetite was easily determined by boiling the tailings with concentrated hydrochloric acid. In other cases, however, the gangue contains ferriferous minerals, besides magnetite, soluble in hydrochloric acid. As evidence of the difference between the total iron and that extracted by boiling hydrochloric acid, it may be noted that of 29 analyses made during six months of 1891 the average total iron was 11·384 per cent., whilst the iron soluble in hydrochloric acid was 9·318 per cent.

The magnetic concentration of iron ore at the Weldon mine, New

* *Transactions of the American Institute of Mining Engineers*, Glen Summit meeting (advance proof).

Jersey, is described by Mr. A. Sahlin.* The mine produces about 350 tons of magnetic ore daily from a vein 5 to 10 feet wide. The ore is interspersed with apatite, hornblende, and felspar, and contains on an average 40 per cent. of iron and 0.40 per cent. of phosphorus. Half the ore, containing 62 per cent. of iron, is picked out by hand. The low-grade ore, containing from 0.75 to 1 per cent. of phosphorus and 30 to 35 per cent. of iron, is passed through a crusher and Krom rolls to an 8-mesh revolving screen, and then to a Lovett-Finney magnetic separator. This consists of a drum over which travels a canvas belt. A copper apron, following the curvature of the drum, is placed under it, and the ore is carried down this apron by a copious stream of water. The drum is built up of two iron discs on a shaft; between them is a solenoid, and from either disc alternately extend iron rods so as to nearly touch the opposite disc, and the whole is filled in with insulating material. The tailings are washed away by the water whilst the magnetic material is attracted by the magnetic drum and carried away over its top by the belt. The drum is 30 inches in diameter and 50 inches long; it makes 14 revolutions per minute, and is supplied with a current of $13\frac{1}{2}$ amperes and 110 volts. The dynamo takes 3 and the separator 30 horse-power. The concentrates during the last six months have averaged 67 per cent. and the tailings 8 per cent. of iron. The phosphorus has been reduced from 0.75 to 0.05 per cent., a reduction of 93 per cent.

The Finney magnetic separator is also described in the *Iron Age*.†

It is anticipated ‡ that there will shortly be erected in the States of New Jersey and New York concentrating plants which will treat nearly 3000 tons of ore a day. In the Lake Champlain and Adirondack district, concentrating works exist at Benson, Port Henry, and Chateaugay. The Tilley-Foster plant is treating low-grade ore near Brewsters, and the Croton concentrating plant is widely known. Other concentrating plant is being erected at Croton Falls. In New Jersey, Mr. Edison is experimenting on a large scale; a Weldon plant is in active work, and a Buchanan separator is in use at Rockaway.

The description of the Hoffmann magnetic separator is now published.§ The chief feature of novelty consists in the use of a "stratifying magnet," over which the ore passes before reaching the separating magnets. The former consists of a number of magnets of alternate

* *Engineering and Mining Journal*, vol. lli. p. 588, with illustrations.

† Vol. xlviii. p. 496, two illustrations.

‡ *Iron Age*, vol. xlviii. p. 1030.

§ *Engineering News and American Railway Journal*, vol. xxvi. pp. 620-621.

polarity, so that the particles of ore tend to arrange themselves in heaps following the lines of magnetic force. At the same time, however, they are carried forward by the travelling belt, and the resulting wave-like motion causes the magnetic particles to gather at the bottom whilst the gangue goes to the top, and a scouring action at the same time is said to result. The finishing magnets are arranged in semi-circular form inside a drum over which the belt passes. The centrifugal action assisted by the magnetic action divides the material into four portions, the lightest being thrown off at once, whilst the heaviest and therefore purest ore is retained till the last. The gangue is discharged periodically through counterweighted gates, and the middlings are repressed through the machine. The belt is of india-rubber with retaining strips on its edges, and is kept tight by moving the rear or driving drum by screw gear. An air blast is caused to circulate among the wire coils of the magnets to keep them cool. The work done with this machine at the Croton mines has been described by Mr. W. H. Hoffmann.*

Illustrations are also published in the *Iron Age*† of the Hoffmann magnetic concentrator in use at the Croton iron ore mines, New York. The following are results obtained in the months mentioned of the year 1891 :—

Months.	Composition of Product.				Iron in Tailings.
	Fe.	P.	S.	Si.	
June	68.55	0.036	0.240	3.50	10.10
July	68.08	0.036	0.340	3.60	9.30
August	68.25	0.030	0.475	2.40	8.41
September	70.09	0.045	0.170	2.50	8.02

The shipments of concentrates for the months of October and November averaged 65.85 per cent. of iron, 0.05 phosphorus, and 0.67 sulphur, the iron in the tailings amounting to 7.67 per cent.

The crude ore varied in iron from 26 to 40 per cent., a fair average being about 33. The phosphorus averaged 0.30 per cent., and the sulphur as much as 2.50.

* *Journal of the Iron and Steel Institute*, 1891, No. II., p. 160.

† Vol. xlviii. p. 1019, three illustrations.

IV.—*METALLURGICAL PREPARATION.*

Incline Truck Drop for Calcining Kilns.—A new incline truck drop for use in connection with calcining kilns is described by Mr. C. Wood.* This drop was designed for lowering the trucks from the top of the kilns at the Tees Ironworks, where the space was very limited, and for that reason a drop of the ordinary design was not admissible. After a description of the form of drop usually employed in the district, the details of the later design are given. Four columns support girders, on which is mounted a shaft with four rope pulleys and a brake-sheave. The counter-balance weights work inside the two main columns. These stand on one side of the centre line of the kilns, from which the truck is run on to the lowering table, its weight being so placed as to keep the guide-wheels in position. The table at the bottom of its travel is tilted automatically, and the stops withdrawn so as to discharge the trucks on the same side as that on which they were received.

* Paper read before the Cleveland Institution of Engineers, April 4, 1892.

REFRACTORY MATERIALS.

Analyses of Fireclay.—Seger * gives the following analyses of fireclay (I.) from Trpiss, in Bohemia, (II.) from Obergartzem, in the Eifel, and (III.) from Groden :—

	I.	II.	III.
Silica	49·42	73·44	66·95
Titanic oxide	0·63	...	...
Alumina	35·83	16·67	26·42
Ferric oxide	1·36	1·13	0·32
Lime	...	0·47	...
Magnesia	0·55	0·55	...
Potash	1·11	...	0·58
Water	11·46	6·82	6·60

Fireclay from Maryland.—The clay from Mount Savage, Allegheny county, Maryland, from which the Mount Savage firebrick is made, according to Mr. L. P. Kiunicutt and Mr. J. F. Rogers,† is found as a hard rock-like mass in veins from 7 to 14 feet wide, which appear to be of Carboniferous age. The stuff is obtained by blasting, and, after weathering, it becomes more friable. It is of a grey or dark-brown colour, almost infusible before the blowpipe, and has a specific gravity of 2·54, and a hardness of 3·5. An analysis gave :—Silica, 31·84 per cent. ; kaolin ($2\text{Al}_2\text{O}_3, 3\text{SiO}_2, 4\text{H}_2\text{O}$), 67·07 per cent. ; ferric oxide, 0·89 per cent.

A complete analysis gave the following result :—

Silica.	Alumina.	Ferric Oxide.	Carbon.	Alkalies.	Water.
60·19	29·10	0·89	0·02	0·03	9·88

Lime was absent, and only traces of magnesia were found. The combined silica was 28·09 per cent.

Graphite.—W. Luzi ‡ has shown that what has hitherto been called “graphite” is divisible into graphite proper and into what he terms

* *Thonindustrie Zeitung*, 1892, Nos. 2, 9, 10.

† *Journal of Analytical and Applied Chemistry*, vol. v. pp. 10, 542.

‡ *Berichte der Deutschen chemischen Gesellschaft*, vol. xxv. p. 214.

“graphitite.” They differ in their behaviour towards nitric acid. Of the thirty-one different varieties of “graphite” the author examined fifteen proved to be graphitite.

Magnesia Bricks in the Blast Furnace.—Dr. Leo* discusses the use of magnesia bricks as a lining for the crucible portion of the blast furnace. He shows that at a blast furnace of the Rombach Works in German Lorraine such a lining has been in use since June 1890, the furnace being worked during this period at its full capacity. It has given much better results than a carbon brick lining in another furnace at the same works. No hot places have shown themselves, nor has the lining been eaten through. Should the furnace be rebuilt, this magnesia lining will be considerably extended.

Similarly, at the Kladno blast furnace in Bohemia a magnesia lining has been in most successful use for over two years. The author quotes from various writers with reference to the superiority of magnesia linings over others of various kinds.

Basic Linings for Converters.—The Hermets basic lining for converters consists of blocks of burnt non-siliceous or magnesian limestone. The limestone is burnt in large masses with great care, so that it does not break up, and is then sawn into blocks of the required size by a band-saw. The dust is saved for succeeding operations. The blocks are laid in place before they can absorb moisture, and are cemented together with boiling pitch or tar, into which they may be dipped directly they are sawn. The sawn blocks may be burnt a second time.†

Basic Brick Press.—The Aiken press for basic brick manufacture is illustrated in the *Iron Age*.‡ In practice, when one of the matrices of a mould wheel is directly above a ram, the ram is moved, and this drives a mould plunger and compresses the basic material in the matrix of the mould against a block placed above it. The pressure is then withdrawn, the ram falls back, and the mould wheel turns through a sixth of a revolution, the compressed material being partially ejected by a movement of the plunger. By gradual forward movement the brick is finally completely ejected, six bricks being formed during one revolution of the mould wheel.

* *Stahl und Eisen*, vol. xi. p. 984.

† *La Métallurgie; Engineering and Mining Journal*, vol. liii. p. 208.

‡ Vol. xlviii. p. 778.

FUEL.

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I.—CALORIFIC VALUE.

Calorimetry.—P. Mahler * has devised a cheap and durable modification of Berthelot's calorimetric bomb.† The chief alteration is in the combustion chamber, which, instead of consisting of platinum, is made of mild steel enamelled inside. The inlet is closed by a screw stopper and the oxygen for combustion is supplied at a pressure of twenty-five atmospheres through a stopcock in the stopper. The other details are constructed on the original model with slight alterations with a view to reduce cost. Trial determinations made with this instrument have given good results.

M. C. Talansier ‡ also describes the Mahler calorimeter. The following are some of the results obtained :—

Fuel.	Analysis.				Calorific Power, Calories.
	C.	H.	O.	N.	
Flaming coal, Blanzv	84·265	5·273	9·262	1·20	8,350
Gas-coal, Commentry	85·664	5·604	7·682	1·05	8,408
Gas-coal, Lens	87·261	5·436	6·263	1·04	8,745
Bituminous coal, Saint-Etienne .	89·231	5·026	4·586	0·89	8,857
Semi-bituminous coal, Anzin . .	91·256	4·269	3·255	1·22	8,656
Anthracitic coal, Tonquin . .	93·456	3·065	2·825	0·65	8,532
Anthracite, Pennsylvania . .	95·373	2·201	1·596	0·83	8,256
Coke	98·051	0·490	1·198	0·261	8,073
Petroleum, America	86·894	13·107	...	...	10,913
Petroleum, Russia	87·905	12·989	...	...	10,843

* *Comptes Rendus de l'Académie des Sciences*, vol. exiii. pp. 800–801.

† *Journal of the Iron and Steel Institute*, 1887, No. II. p. 234.

‡ *Génie Civil*, vol. xx. pp. 197–201.

The Calorific Power of Coal Distillation Products.—P. Mahler * gives the following results of determinations of the calorific power of various products resulting from the distillation of a coal :—

Material.	Calorific Power, Calories.	Weight, Kilogrammes.
Coal	7,423·2	100·00
Coke	7,019·4	65·66
Tar	8,538·4 to } 8,942·8	7·81
Gas, dry	11,111·0	17·09
Ammonia water	...	9·36

P. Mahler † finds that the sum of the calorific powers of the products of distillation of Commentry coal was 96·5 per cent. of the calorific power of the original coal.

The following are the calorific powers at constant volume of some samples of coal-gas :—

	Calorific Power per Cubic Metre.	Specific Gravity.	Calorific Power per Kilogramme.
Gas made at La Villette . .	5,601·9	0·4033	10,744
Gas from Commentry coal . .	5,804·0	0·4040	11,111
Gas from Niddrie cannel . .	6,365·5	0·6367	7,735

The Behaviour of Coal during Combustion.—Mr. B. Holgate ‡ describes the variations of the behaviour of coal during combustion. Cannel coal contains a considerable quantity of fish remains, and was deposited under water. When coked, the lumps retain their original shape. Most other coals are somewhat similar in composition to one another, so that analysis alone will not determine their burning qualities. The appearance of the coal is a much better guide. Some coals require a high temperature and a strong draught to burn properly, such as the Better Bed coal of Yorkshire. As a general rule, coal which breaks naturally into small will not deliver its gas so freely and will not burn so readily, but it makes the best coking coal when it is

* *Journal des Usines à Gaz*, vol. xvi. p. 44.

† *Comptes Rendus de l'Académie des Sciences*, vol. cxiii. pp. 862-864.

‡ Lecture delivered before the Yorkshire College Engineering Society, December 7, 1891, through the *Colliery Guardian*, vol. lxii. p. 1014.

soft and breaks up easily. When the coal breaks into large lumps the gas can get away more readily.

The Valuation of Fuel Gas.—Mr. E. G. Love * shows the desirability of determining the value of fuel gas, and gives as the number of heat units obtained from a cubic foot of gas at 60 F. and 30 inches pressure—

	Lb. Fahr. Units.
Carburetted water-gas, New York	721
Mixtures of coal-gas and water-gas, New York	694·7
Illuminating gas, London	668
Miscellaneous fuel gases, 184 to 470, average	309

The determination of the calorific value may be determined in a proper calorimeter or by calculating from the composition, the first method being the easiest and the most preferable. For this purpose a calorimeter devised by Mr. F. W. Hartley is described. In this device, the gas is burnt in a Bunsen burner, and the heat is absorbed by a system of water-jackets and passages. Carefully graduated thermometers are used, and each test requires ten to fifteen minutes, a quarter of a cubic foot of gas being used. A sample test is given to show the precautions to be observed and the corrections to be made.

The results of some boiler evaporation experiments with solid, liquid, and gaseous fuels are given by Mr. M. Livingston.† The weight of water evaporated per pound of fuel was:—Anthracite, 9·70 lbs.; bituminous coal, 10·14 lbs.; fuel oil, 16·48; and for one cubic foot of gas of 20-candle power, 1·28 lb. It is urged that the loss of heat when working with liquid fuel is less than in the case of solid fuel.

Efficiency Tests of Coals.—In a series of articles, Mr. W. Kent ‡ gives a critical review of efficiency tests of coals, dealing mainly with tests made by Professor W. R. Johnson nearly fifty years ago, and comparing them with more modern tests. The earlier tests were made on forty-one samples of coal, including nine anthracites, twelve semi-bituminous, and eleven American bituminous coals. These tests were mainly evaporating tests made in a steam-generator, and they are often now quoted. Gruner's researches are also quoted, and Johnson's results are recalculated to bring them into accord, and the results are plotted. The difference between the results is discussed, and ascribed

* *The School of Mines Quarterly*, vol. xiii. pp. 97–104.

† *Proceedings of the Engineers' Club of Philadelphia*, vol. ix. pp. 82–92.

‡ *Engineering and Mining Journal*, vol. lii. pp. 430, 450, 504.

partly to the difficulty of completely burning bituminous coals as compared with anthracite, which does not give off so much volatile matter.

Bohemian Coals.—Professor H. Bunte * has made a series of calorimetric studies of Bohemian coals. Those he examined had the following percentage compositions when air-dry :—

	C.	H.	O.	N.	S.	Water.	Ash.
Lignite	65.77	5.02	15.54		0.66	10.01	3.00
Plattell coal lumps	60.07	5.66	7.76	1.16	1.16	3.04	21.15
Nuts	59.96	5.56	7.93	1.00	1.08	3.23	21.24

The results actually obtained with these fuels in the calorimeter, and those resulting from the theoretical determination of the calorific power based on the percentage, are as follows :—

	Actual Calories.	Theoretical Calories.	Difference Per Cent.
Lignite	6220	6218	0.0
Coal lumps	6205	6150	+0.9
Nuts	6234	6188	-0.7

The results of a number of other analytical and calorimetric determinations are also given by the author,† and these, too, show that, like the above, the actual and theoretical results of calorimetric determinations closely approximate to each other.

Pyrometry.—In a lecture on pyrometry delivered before the Society of German Manufacturers of Refractory Products, Professor Seger ‡ expressed the opinion that pyrometers which are based on the expansion of metals are absolutely untrustworthy above a visible red heat, as the rods on cooling do not assume their original volume. Air pyrometers, which give good results at low temperatures, are inapplicable at high temperatures, inasmuch as the walls of the vessel itself expand on heating, and platinum is permeable by gas at high temperatures. Siemens' electric pyrometer gives good results at low

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 531.

† *Bayerisches Industrie und Gewerbe-Blatt*, vol. xxiii. p. 397.

‡ *Berg- und Hüttenmännische Zeitung*, vol. li. pp. 90-91.

temperatures. Above the melting-point of silver, however, the determinations are not concordant, and the differences are too great. The safest results are obtained by the method based on the melting of metals and glasses. The precious metals alone are suitable. With gold-silver alloys the results are very satisfactory, but they only include a limited difference of temperature of about 125°. Of gold-platinum alloys only those containing less than 15 per cent. of platinum are suitable. When the proportion of platinum exceeds this, an easily fusible alloy liquates. With base metals, on account of their oxidisability, it is only possible to measure temperatures below a red heat, but with precious metals measurements may be made up to 1150°.

The optical pyrometer of Mesuré and Nouel does not admit of accurate measurements, because the appreciation of the various shades of colour varies widely with different eyes, and the angle of rotation for very different temperatures is so close, and accurate setting is so difficult, that the colour cannot be determined much more accurately than it can be with a little practice with the eye alone.

The method employed at the Sèvres porcelain manufactory, which consists in placing in the furnace a copper tube through which passes a current of water whose increase in temperature is measured, is also not entirely trustworthy, inasmuch as the results are dependent on the conductivity of the copper tube, and this is influenced by the deposits of scale. The calorimeter gives satisfactory results, but this too is insufficient for the highest temperatures, because the specific heat of the iron or platinum heated is known only at low temperatures, and has a different value at high temperatures.

In cases where pyrometric methods have failed, a scale of refractory clays has been found useful. Thus Bischof has devised a scale of normal clays of various degrees of fire-resistance, whilst Seger employs a highly refractory clay, the Zettlitz clay, mixed with quartz in various proportions, obtaining a scale of thirty-five samples. The first represents a temperature of 1150° C., and No. 20 represents the highest temperature attained in the porcelain kiln, about 1700° C.

A description of Wiborg's air pyrometer * is given by Mr. J. Crum.†

The Determination of High Temperatures.—M. H. Le Chatelier ‡ observes that an optical method for the determination of high

* *Journal of the Iron and Steel Institute*, 1891, No. II., p. 130.

† Paper read before the Institution of Engineers and Shipbuilders of Scotland; *Industries*, vol. xii. pp. 522-524.

‡ *Comptes Rendus de l'Académie des Sciences*, vol. cxiv. pp. 214-216.

temperatures would be extremely accurate, provided the lengths of the emitted waves could be readily ascertained, and the condition of the bodies heated and of their surroundings constant and uniform. A modified form of the Cornu photometer seems best suited for this purpose. The author gives the results of some experiments.

The Temperatures of Furnaces.—M. H. Le Chatelier* gives the following as the temperatures of various metallurgical furnaces, and of the melting-points of certain metallurgical products, compared with the Rolle scale:—

S. 448°	Al. 1045°	Pd. 1500°	Pt. 1775°
Grey pig iron, melting-point	.	.	1220°
White pig iron, „	„	.	1135°
Mild steel, 0·1 C. „	„	.	1475°
Steel, 0·3 C. „	„	.	1455°
Steel, 0·9 C. „	„	.	1410°
Bessemer converter, spark shower period	.	.	1330°
Bessemer converter, end of operation	.	.	1580°

The Bessemer process working a 6-ton charge showed the temperature of the slag at pouring 1580°, of the metal in the ladle 1640°, and in the moulds 1580°. The solidifying iron scale showed 1340°, the reheating furnace 1200°, and the ingot under the hammer 1080°. The open-hearth working on 0·3 steel gave as the temperatures: gas leaving producer, 720°; on entering regenerator chamber, 400°; on leaving regenerator, 1200°; air leaving regenerator, 1000°; and chimney gases, 300°. The furnace at the end of the melting of the pig iron, 1420°; at the end of the charge, 1500°; of the steel on pouring, 1580° to 1490°; and when in the mould, 1520°.

A Siemens crucible steel furnace varied between 1230° and 1330°. A blast furnace making grey Bessemer pig iron showed 1930° in front of the tuyeres, and the metal at the commencement of tapping 1400°, and at the end 1570°.

The Hoffmann brick kiln reaches 1100°.

II.—COAL.

The Soluble and Resinoid Constituents of Coal.—Mr. Watson Smith † gives the results of some determinations of the soluble resinoid

* *Comptes Rendus de l'Académie des Sciences*, vol. cxiv. pp. 470-473.

† *Journal of the Society of Chemical Industry*, vol. x. pp. 975-980.

constituents in some cannels, and in a Japanese coal of bituminous character. A short resumé of the researches of other investigators is also given. Rectified benzene, distilling between 80° C. and 82° C. was used as a solvent, and the following table shows the results:—

	Per Cent.
Scottish boghead cannel	0·6
Australian cannel	0·67
American cannel (Breckenridge, Virginia), ...	1·06
Hucknall cannel, Lancashire	1·06
Tyldesley cannel, Lancashire	0·85
Miike coal, Japan	9·5

This latter coal is obtained in the Miike Colliery, which is close to the sea in Kiushiu Island, Japan. The existence of coal was known 400 years ago, but little importance was attached to it until 1873. Three years later the mine produced 300 tons per day, but in 1885 a shaft was opened to a depth of 240 feet, and the daily production increased to 1200 tons. In 1888 the mine was sold for £750,000, and the production has now increased up to 2000 tons daily. The coal exists over an area of 3758 acres, and is estimated to contain some 85,444,000 tons of coal. There are two harbours near Miike, and a railway is being built to the nearest, which is 18 miles distant. A new shaft, 400 feet deep, is being sunk. Most of the labourers employed are convicts.

The seam is of an average thickness of eight feet, and is of uniform quality and free from shale. Boiler reports show that the coal is of good quality for steam-raising purposes. The specific gravity of the coal is 1·269, the calorific value 7616 British thermal units, the ash is reddish-white and averages 9·45 per cent. An analysis of the ash gave:—

Silica.	Ferric Oxide.	Alumina.	Lime.	Sulphur.
14·94	10·87	10·04	42·38	11·24

The high percentage of lime is thus very remarkable, and indicates that the vegetation from which the coal was formed grew on a chalky soil.

Two analyses of the coal gave the following results:—

Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Moisture.
75·22	5·84	1·11	3·15	0·62
74·88	5·91	...	3·13	0·65

A test in a Simon-Carvès oven yielded 60 per cent. of a dense hard coke, containing 83·88 per cent. of combustible matter, 15·80 of ash, and 0·32 of moisture. The sulphur amounted to 0·57 per cent. as

calcium sulphate, and 2.54 per cent. as calcium monosulphide, a little only existing as iron sulphide.

The following table shows the effect of distillation on this coal as compared with gas-coal and Wigan canal:—

Description.	Gas, Cubic Feet per Ton of Coal.	Illuminating Power, Candles.	Coke, Lbs. per Ton of Coal.
Miike coal	11,033	23.42	1,297
Ordinary gas-coal	12,033	18.76	1,512
Wigan canal	13,069	20.78	1,441

The extract of the coal in benzene when freed from the solvent gave the following percentage results on distillation at the given temperatures:—

Centigrade	175° to 200°	250°	300°	Over 300°	Higher Temps.	Residue.
Per cent.	3.2	4.0	9.6	21.3	107	48.9

Paraffin crystallises out from that portion distilling above 300° C., so that it is analogous to the lubricating oils obtained from American petroleums. This bituminous matter is apparently not due to the action of heat on the coal, but consists of the altered resins from the spores and fruits of a former vegetation, a further stage of what Dr. R. Angus Smith found in the case of peat-oils and waxes, and Dr. Percy in the case of lignites. The author thinks that this offers an explanation of the origin of petroleum, though other theories may at the same time be also true. In some of the latter, the absence of nitrogenous matter is not satisfactorily explained. Further experiments on this coal are, however, promised.

Mineral Resins from the Caucasus.—W. Alexéeff* has investigated the Caucasian elaterites and dopplerites. The so-called elaterite from the government of Kutais, two miles from the Notanebi Railway Station, proves on analysis to be dopplerite, the analytical results being as follows:—

Carbon.	Hydrogen.	Oxygen and Nitrogen.	Ash.
51.17	4.60	34.57	9.66

The percentage of hygroscopic water was 7.28. The composition is quite analogous to that of the coal of Lepsia in the north of the Ural Mountains. The author regards dopplerites as being intermediate

* *Zeitschrift für Krystallographie und Mineralogie*, vol. xx. pp. 187-188.

between the bituminous coals and lignites. Pure elaterites, on the other hand, are probably nothing more than asphalt $n(\text{CH}_2)$, with which a small proportion of an oxygen compound is mixed. An analysis of elaterite from Sakupris Gelle, near Notanebi, gave the following results:—

Carbon.	Hydrogen.	Oxygen and Nitrogen.	Ash.
84.66	8.19	4.93	2.19

Occurrence of Mineral Resin in Lignite.—The occurrence of mineral resin in some of the coals and lignites of Canada has been known for many years, and the results of an examination, conducted under the auspices of the Geological Survey in 1877, showed that none of the specimens could be classed as amber, though in some respects they closely resembled that substance. Attention was also called to the statement of Goeppert that he knew of no instance of true amber being found in the brown coals of Germany, the substance occurring in those beds being retinite.

In 1890 a mineral resin resembling amber was found in large quantity by Mr. J. B. Tyrell, of the Geological Survey of Canada, on the west shore of Cedar Lake, near the mouth of the North Saskatchewan. It occurs mixed with sand and partly decayed wood, and has evidently been washed up on the shore by the waves. On examination by Mr. B. J. Harrington,* it was found that, although resembling amber in some of its characters, this resin may be classed provisionally as retinite, seeing that it differs from true amber in its behaviour with acids, in its not yielding crystals of succinic acid on distillation, and in its somewhat different ultimate composition. Though its origin is not known with certainty, there can be no doubt that it was derived from one of the Tertiary or Cretaceous lignites occurring on the Saskatchewan.

The Gases Enclosed in Coal and Coal-Dust.—Professor P. P. Bedson† and Mr. W. McConnell have further investigated the gases given off by coal and coal-dust. Coal from the Hutton seam, Rhyhope Colliery, was broken into small pieces and heated in an exhausted flask for 119 hours. The gas given off had a volume ten to eleven times greater than that of the coal, and had the following composition by volume—

* *American Journal of Science*, vol. xlii. pp. 332-335.

† *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 307-310.

Carbonic Anhydride.	Oxygen.	Carbonic Oxide.	Olefines.	Marsh Gas.	Nitrogen.	Total.
0·7	9·4	0·1	0·0	16·6	73·0	99·8

The coal was then crushed to powder and again treated, the gas then given off containing—

Carbonic Anhydride.	Oxygen.	Carbonic Oxide.	Olefines.	Paraffins.	Nitrogen.	Total.
0·85	6·95	trace	1·10	17·90	73·20	100·00

The olefines are of the form C_nH_{2n} , the paraffins C_nH_{2n+2} , the n in the latter case being greater than 2. From this it is evident that the heavier hydrocarbons are more firmly held in the coal, and are only liberated after crushing. Further researches are promised.

Spontaneous Combustion of Coal.—In a paper discussing the geology and method of working in the South Staffordshire coalfield, Mr. F. W. Clark and Mr. H. W. Hughes* give a summary of the question of spontaneous combustion of this coal, to which it is exceedingly liable. There are three factors, oxidation of the organic constituents, the iron pyrites, and the pressure. The first is undoubtedly the main cause, but it is assisted materially by the last. Decomposition of the pyrites may break up the coal and thereby expose a larger surface, but the heat generated by it is small. Heating is due to the absorption of oxygen by the coal, and is favoured by heat, moisture, and fine division. The pressure may also produce heating by the friction from the crushing of the coal, besides which the freshly-broken coal absorbs oxygen more freely. Spontaneous combustion is almost unknown in the seam known as the sulphur or stinking coal, which contains large quantities of pyrites. For the prevention of spontaneous combustion, all slack and refuse should be removed, and the ventilation should be good to cool the coal. Lines of water mains are also laid in the principal roads. If the coal does take fire, the only practical treatment is to dam off the place where the fire exists.

As a sequel to a former paper† on the spontaneous ignition of coal, Mr. V. B. Lewes‡ has presented a second, dealing with this subject and its prevention. The reasons for spontaneous combustion are again pointed out, and it is shown that it is due to the rapid absorption of oxygen by freshly-broken surfaces of the coal, followed by oxidation of the carbonaceous matters and the consequent heating effect. The methods described for its prevention have chiefly to do

* *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 45–49.

† See *Journal of the Iron and Steel Institute*, 1891, No. II. pp. 171–173.

‡ *Journal of the Society of Arts*, vol. xl. pp. 352–365.

with shipping of coal, but some of the suggestions advanced are useful in other circumstances. Coal for shipment should be in large pieces, as free from small as possible. It should be kept under cover, and should never be loaded wet nor when it has been freshly mined. A month should be allowed to elapse between mining and loading, and it should be as little broken up as possible during that process. On the boat itself, the coal should be protected from all extraneous sources of heat, such as boilers, flues, &c. In the case of coal cargoes, the coal should not be ventilated, so that once the oxygen in the hold is absorbed, no more can get at the coal, but in coal-bunkers the ventilation should be good. The use of compressed carbonic anhydride for cooling purposes is advocated.

The South Staffordshire Coalfield.—Mr. W. F. Clark and Mr. H. W. Hughes * give a general description of the South Staffordshire coalfield south of the Bentley fault, and the methods of working the ten-yard or thick coal. This field has an irregularly spindle-shaped figure, the beds dipping southwardly and the Coal measures resting directly on the Upper Silurian formation. At the Bentley fault on the north the downthrow of 120 yards brings in the Coal measures again to form the north part of the field. The east and west boundaries are also formed by faults beyond which coal has been proved on the east, and it will probably also be found on the west. In the interior of the field there are two marked anticlinals, one running from Parkfield to Dudley and the other is the Netherton anticlinal. A very large number of faults occur in this field, and a short description is given of the chief of these, namely, the trough faults of Brierley Hill and of Dudley Port, and also the Russell's Hall, Tipton, Ball's Hill, and other faults. The Dudley Port trough fault marks the line of most intense strain, southward of it the faults have downthrows to the north and northward to the south. The igneous rocks in this district were formed after the Coal measures, but before the extensive faulting took place.

As regards the stratigraphy of the district, the coal seams remain fairly constant in thickness, but the intermediate beds thin out towards the south. A general section is given, however, to show every workable bed of coal and ironstone in its proper place, without regard to locality. Twenty-three seams, of which fourteen make up the thick

* *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 25-49.

coal and sixteen iron ore horizons are thus shown, and an account is given of each coal seam and of the subdivisions of the ten-yard coal.

The part of the South Staffordshire coalfield which lies north of the Bentley fault is described by Mr. A. Sopwith.* As stated above, the downthrow of 120 yards at this fault brings in the Coal measures and forms a small field which is somewhat triangular in form, 7 miles broad at the base and 10 miles long. The thick coal of the southern part of the field is here broken up into its several component seams, the separation beginning south of the great fault. Lower Carboniferous strata are absent, and the Coal measures rest directly on the Silurian limestones. Above the Coal measures some red beds are found, which have generally been thought to be of Carboniferous age, but it is not quite certain whether they might not belong to the Permian formation. The lower seam of coal is separated from the Silurian rocks by measures which increase considerably in thickness towards the north. Workable coal aggregating some 40 to 45 feet in thickness prevails uniformly through the district, but the seams chiefly worked are the Shallow and Deep seams, the lowest ones of the series. The field is exceedingly dislocated by a large number of faults, whose throw is very variable from point to point. The effects of the faults are then discussed, and the various features of interest in the field are pointed out by the author. Sections of various parts of the field are appended. The method of work employed is the long-wall, and the total output of the district is estimated at five million tons yearly.

In the course of a sketch of the geology of the Birmingham district, Professor C. Lapworth † deals with the Carboniferous measures in the neighbourhood. The New Red Sandstone here stretches out into a belt of nearly fifty miles wide, with eroded patches through which the Coal measures crop out. This occurs in three main areas on the crests of eroded anticlinal arches in the South Staffordshire field, in the East Warwickshire and Ashby-de-la-Zouch, and in Coalbrookdale and the Forest of Wye. Both the Carboniferous limestone and the Millstone grit are practically absent in the Midlands, while the other beds also thin out. At the same time, the seams of coal retain their thickness, and where the intermediate beds have altogether disappeared the various beds of coal form one thick seam, as in the ten-yard coal. In the north of the South Staffordshire field there are nineteen distinct coals in a thickness of 800 feet, and these become seven seams in a total thickness of 350

* *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 50-60.

† *Ibid.*, vol. iii. pp. 10-24.

feet in the south. It would appear that the Carboniferous strata in all these fields were laid down in the same broad geographical basin, the northern limits of which lie in Scotland, its deeper parts to the north and west of the Midlands, where all the strata are fully developed. The shallower margins lie to the south and south-east in the Birmingham district, and here all the older formations are absent. The coal seams come together and then become impregnated with shaly matter, showing the extreme edge of the Carboniferous basin in this direction.

The Somersetshire Coalfield.—With the aid of a geological map and numerous sections and plates, Mr. G. E. J. M'Murtrie * describes the geology of the Somerset coalfield and the method of working the seams. The extreme length of the coalfield is 26 miles and its breadth 12 miles, making an area of 238 square miles, of which 190 are covered by recent formations, consisting of the Oolite, the Lias, and the New Red Sandstone. The newer formations are conformable with one another, and are nearly horizontal, whilst they are unconformable with the older formations, upon whose upturned and denuded edges they rest. The absence of the Permian is a notable feature of this unconformability.

The Radstock series, 250 feet thick, contains six workable coal-seams, together equal to 11 feet 4 inches of coal, of good quality. The Farrington series, 310 feet thick, contains 10 feet 8 inches of coal in six seams. The Pennant Sandstone contains a few subordinate seams. The Lower Coal series follows, and is in two divisions—(1.) The New Rock series, with 54 feet of coal in eighteen workable seams, and (2) the Vobster series, with 28 feet of coal in eight seams. Of all the districts in England this is the most faulted, being comparable in this respect to the French and Belgian coalfields. From a list of forty faults, ranging from 8 to 100 fathoms, the most striking are described, including the Radstock overlap fault, where the amount of overlap is 120 yards in the uppermost seam and 330 yards in the lowest one.

The methods of working, usually some modification of long-wall to suit the varying dip, and of ventilation, are fully described. The Radstock, Farrington, and New Rock series are free from gas, and are worked with candles; but the Vobster series is very fiery.

Coal in East Anglia.—The boring recently abandoned at Culford

* *Journal of the British Society of Mining Students*, vol. xii. No. 6.

Hall, near Bury St. Edmunds, according to Mr. W. H. Dalton,* has penetrated rocks of Silurian age. The Lower Greensand was reached at a depth of 600 feet from the surface, and 36 feet lower a hard green slate, dipping at 30°, was encountered. The boring was stopped at a depth of 657 feet 3 inches, as it was clear that Palæozoic rocks, probably the Wenlock division of the Upper Silurian series, had been reached.

The probability of coal being found in East Anglia is discussed by Dr. J. E. Taylor.† Up to the present time no coal has been found in any of the borings that have been made, with perhaps the exception of pebbles of coal in the drift beds. The main question is the possibility of the continuation of the Coal measures of Somersetshire under these counties to connect with those in Belgium and North France. Coal has already been proved in Kent, and it is found to lie on an anticlinal axis, so that the coal should be found, as it is on the east and on the west, in basins of considerable length as compared with their breadth. A boring should be made a little farther to the north of Culford, somewhere on a line through Southwold, Eye, and Mildenhall.

The Kentish Coalfield.—Further details of the discoveries in the Kentish coalfield have been given by Professor Boyd Dawkins.‡ Altogether nine seams of coal have been found, the first being 27 feet from the top of the Coal measures. The details of the seams are as follows :—

Number of seam	1	2	3	4	5	6	7	8	9
Thickness in feet	2½	2	2	1½	1	2½	2½	2½	...
Depth in feet	1140	1231	1279	1313	1434	1458	1614	1808	1875

This field appears to be more closely related to those of Northern France and Belgium than to any other. The calamites and other characteristic fossils prove that the coal is of the true Carboniferous age. The total thickness of all the seams is over 17 feet, and out of that Mr. Brady estimates that there is a workable thickness of 14 feet in a depth of 762 feet of the measures. From an examination of large cores, the dip of the beds appears to be 1 in 28, and this low dip indicates that large faults are probably absent. There is every reason to suppose that these beds extend eastward to Calais, where coal has

* *Colliery Guardian*, vol. lxii. p. 1013.

† Lecture at Bury St. Edmunds, through the *Colliery Guardian*, vol. lxii. p. 983.

‡ *Transactions of the Manchester Geological Society*, vol. xxi. pp. 456-474.

been struck at a depth of 1140 feet below high-water mark. The seams are well within a workable depth, as coal is now being worked in England at depths exceeding 3000 feet. The coal itself is very soft and very bright, and it appears to have a cubical fracture.

Coal in the Isle of Man.—Coal has been sought for on several occasions in the Isle of Man, though without much prospect of success, as is shown by Dr. Haviland,* in an interesting account of some of the ventures. In 1793 the discovery of a seam in the south of the island was announced, but nothing further was heard of it. Sir W. W. Smyth mentions a 3-inch band of anthracite coal on the east wall of the Laxey lode in the 100-fathom level. The Carboniferous limestone may appear in the island, but all coal-bearing measures have been denuded.

The Karwin Collieries, Austria.—A note by Grey is given by Rateau † dealing with the collieries at Karwin, which are situated at the east of the Ostrau-Karwin basin, and near the Silesian coalfield. There are four pits with an annual output of 600,000 tons, and there are 317 coke-ovens. The seams worked, of which sectional illustrations are given, are numbered as shown in the following table, which gives the composition of the coal from each seam :—

Number of Seam.	Volatile Matter.	Ash.	Sulphur.	Phosphorus.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
7	31·32	2·5	1·702	0·084
8	34·00	3·2	1·300	0·009
15	32·45	7·8	0·611	0·186
16	28·18	7·8	1·278	0·041
17	30·06	6·3	0·631	0·031
18	31·50	3·1	1·620	0·007
19, upper part . . .	27·92	5·5	0·360	0·108
19, lower part . . .	31·74	4·0	0·570	0·344
21	29·17	2·8	0·500	0·223
22	29·77	10·6	0·430	0·047

The first two coals give a friable coke, but that from the other seams is good if the coal is coked soon after extraction. A full description is given of the washing plant.

* Paper read before the Manx Geological Society, through the *Colliery Guardian*, vol. lxiii. p. 608.

† *Société de l'Industrie Minérale, Comptes Rendus*, 1891, pp. 241-246, two plates.

A New Coal District.—The Coal measures close to the western frontier of Prussia, extending from Aix-la-Chapelle along the Worm valley, have been worked without interruption for several centuries. More than twenty years ago it was surmised that the Coal measures must extend westwards towards the Maas. This view has been confirmed by the results obtained on French territory, in the Pas-de-Calais, as well as between Valenciennes and Mons, and a number of borings put down in the vicinity of the Dutch town of Heerlen have proved the presence of the Coal measures beneath 30 to 150 yards of Tertiary strata. The extension of the mining operations in the Aix-la-Chapelle coalfield, and deep bore-holes put down by the Prussian Government, have shown that the Coal measures, with all its wealth of coal-seams, must be present in the Dutch district mentioned.

According to F. Büttgenbach,* the results of further explorations have been very satisfactory. Seams 2 feet 6 inches to 5 feet in thickness have been encountered, and it may consequently be concluded that the coalfield contains all the seams known in the Worm district. It thus appears probable that a considerable coal industry will shortly be established in Holland.

The Coal Deposits at Martos, Spain.—At Martos, in the province of Jaén, Spain, borings have proved the existence of several beds of coal, some of which exceed 20 inches in thickness. These deposits are close to the district of Linares, and should they be worked on any large scale, would become of considerable importance.†

Coal in Spitzbergen.—In a paper read before the Berlin Geographical Society, Cremer stated that on a recent journey to Spitzbergen many beds of coal were found on the east coast of Bären Island. The thickest seam was 5 feet in thickness, and coal was exposed along the coast for a distance of $4\frac{1}{2}$ miles. The coal was found in strata of Jurassic and Miocene age.

The Lignite Deposits of Gippsland.—Mr. R. A. F. Murray,‡ Government geologist of Victoria, has published a report upon the country around Boolarra and Yinnar in relation to the lignite discovered there. The deposits vary in character, in some places showing

* *Berg- und Hüttenmännische Zeitung*, vol. li. pp. 1-2.

† *Revista Minera, Metalúrgica y de Ingeniería*, vol. xlii. p. 874.

‡ *Reports of the Mining Registrars*, Melbourne, pp. 82-84.

the distinct woody structure of lignite, whilst in others that structure is so far obliterated that the term "brown coal" would be more suitable.

The lignite of Gippsland is of Miocene age, and has been proved to exist over an area of 100 square miles. Assays of the lignite gave the following results :—

	I.	II.	III.	IV.
Water	18.90	16.40	21.35	36.15
Volatile matter	35.25	33.50	34.58	27.25
Fixed carbon	41.75	37.65	42.10	35.60
Ash	4.10	7.45	1.97	1.00
Totals	100.00	100.00	100.00	100.00

The localities from which these samples were derived were:— I. Haunted Hill seam; II. Elizabeth Creek; III. Darlimurta; IV. Latrobe River seam, worked by the Great Morwell Coal Mining Company.

The proved number of localities where the lignite has been found, the evidences as to its lateral extent, its immense thickness in places, and its qualities as shown by analysis and practical trial, all show that in the lignite deposits of Gippsland lies an amount of stored fuel equal to that of a great coalfield.

Coal in Canada.—The following assays of coal from three seams in the Cape Breton coalfield have been given : *—

Description.	Sydney.	Phalen.	Harbor.
Moisture	1.26	0.92	0.80
Volatile matter, fast coking	35.51	30.31	29.40
Fixed carbon, "	59.11	62.33	65.50
Volatile matter, slow coking	33.84	28.62	27.85
Fixed carbon, "	60.78	64.02	67.05
Ash	4.11	6.48	4.30
Sulphur	1.70	1.10	1.29
Theoretical evaporative power	8.33	8.78	9.19

Coal in Newfoundland.—During the past year, according to an official report, valuable seams of coal have been found in the vicinity of St. Georges Bay. The strata in this district have previously been thought to belong to the Carboniferous limestone and Millstone grit

* *Colliery Guardian*, vol. lxi. p. 254.

series. Sir William Dawson thinks that these seams are similar to those of Eastern Cape Breton, with which they may be continuous under the gulf. A thickness of 27 feet of coal has been discovered, and analysis shows that it is similar in quality to the Cape Breton coal. Large deposits of magnetite exist in the same locality.

South African Coal.—The following table, showing the performance of certain South African coals, has been published : *—

Coal.	Per-centage Values.	Water Evaporated per lb. of Coal.	Coal per indicated Horse-power per Hour.	Theoretical Evaporative Value in lbs. of Water per lb. of Coal.	Theoretical Value of one lb. of Coal in Thermal Units.	Theoretical Horse-power of one lb. of Coal.	Actual.
Good average English	100	9.0	3.0	14.0	14,000	5.4	0.33
Oliphant's River .	81	7.1	3.7	12.1	11,340	4.41	0.27
Steenkool Spruit .	79	6.9	4.4	11.9	11,060	4.31	0.227
Anglo-African .	77	6.7	4.5	11.7	10,780	4.2	0.222
Newcastle Colliery .	77	6.7	4.5	11.7	10,780	4.2	0.222
Brakpan .	71	6.1	4.7	11.1	9,940	3.8	0.21
Black Diamond .	60	5.0	6.03	10.0	8,400	3.2	0.16
Holdfast .	52	4.2	6.4	9.2	6,720	2.6	0.15
Vogelfontein .	43	3.3	7.3	8.3	6,020	2.3	0.13
Average .	...	5.75	5.19	10.75	9,380	3.32	0.199
Average of last six samples .	...	5.3	5.57	10.33	8,773	3.3	0.162

Coal Industry in Natal.—According to a report of the United States Consular Agent at Durban, a large number of coal seams are being worked in Natal, and the largest mine is one of the Dundee Coal Company's opened two years ago. The seam is being worked at a depth of 58 feet, with three shafts and $5\frac{1}{2}$ miles of tramway underground. The pit is 240 miles from Durban and 8 miles from the main line, to which it is connected by a branch line. The seam is level, and there are other untouched seams below. There are employed 25 white men, 200 natives, and 40 coolies. The output for the year 1890 was 40,000 tons. Collieries are being opened, and the native coal has ousted imported coal.†

Coal in Zululand.—It is stated that a valuable seam of coal has

* *South African Mining Journal*, vol. i. p. 96.

† *Colliery Guardian*, vol. lxiii. p. 155.

been discovered within a hundred miles of Durban, near the Tugela River in Lower Zululand.*

Refuse in Anthracite Seams.—The following table summarises some investigations made by Mr. W. Griffith † on the amount of refuse contained in the anthracite seams of the northern anthracite field of Pennsylvania:—

District.	Number of Bed Sections.	Aggregate Thickness of Seams.	Aggregate Thickness of Refuse.	Percentage of Refuses.
		Feet.	Feet.	
Scranton district . . .	33	322·72	57·5	17·8
Pittston district . . .	28	236·5	43·05	18·4
Wilkes Barre district . .	61	593·8	115·9	19·4
Panther Creek basin . . .	28	885·4	162·6	18·3
Totals . . .	150	2038·42	379·05	18·6

The author then uses the figures obtained for each bed to obtain the relative positions in the measures of the several beds in each district in order to show their identity. It is also noticeable that the lower beds, which are also the oldest, contain more refuse than those above. To a certain extent the generalisation may also be applied to the still later coals, the bituminous varieties.

Coal in Alaska.—Several valuable coal-seams have been opened up on the Niga Islands, Alaska, and have been connected by a tramway with a port. The coal is well placed for development, and can be cheaply mined.‡

Tests of Indiana Coal.—Mr. A. F. Nagle§ describes some tests made with Indiana block coal at a pumping station under an ordinary return tubular boiler. The rate of evaporation was 2·53 lbs. per square foot of heating surface, the waste gases escaping at 557° Fahr. One lb. of fuel thus evaporated 10·05 lbs. of water at 212° Fahr. No details nor analyses of the coal are given.

* *Industries*, vol. xii. p. 428.

† *Engineering and Mining Journal*, vol. liii. p. 494.

‡ *Iron Age*, vol. xlviii. p. 969.

§ Paper read before the American Society of Mechanical Engineers, New York, November 1891.

Coal in Kentucky.—Mr. W. B. Phillips* states that a seam of coal 4 feet 9 inches in thickness has been recently opened up in Hopkins county, Kentucky. It yields an excellent coke. It contains 6·45 per cent. of ash, but the sulphur is 1·21 per cent. Most of the coke made in Kentucky is apt to run high in both ash and sulphur, some 12 and 2 per cent. respectively.

In Pike county, Kentucky, there are eight seams of coal having a total thickness of workable coal of more than 38 feet, all above the drainage level. They can consequently be worked by adits, and the cost of mining will be low. One seam, the Elkhorn, is 7 feet in thickness, the coal being a good caking variety. †

The Coal Deposits of Montana.—There exist in Fergus county, Montana, several important coal deposits, one of which is known to have a length of about twenty miles from Swimming Woman's Creek to Careless Creek. Hitherto these coalfields have been but little explored. ‡

Coal in New Mexico.—The following section of the strata in the Gallup coalfield in New Mexico is given by Mr. J. F. Blandy: §—

	Ft.	Ins.
Barren measures	...	...
Coal worked at Gallup mine	6	0
Sandstone containing two four-foot seams of coal	180	0
Barren measures, mostly sandstone	720-880	0
Coal, good but not worked	3	6
Massive sandstone	50	0
Coal	1	2
Sandstone, mostly massive	30	0
Coal	4	0
Slate	6	0
Coal from 5 to 7 feet, worked at Black Diamond Colliery, averaging	6	0
Massive sandstone	35	0
Coal	1	10
Sandstones and shales down to the Dakota measures, probably	200	0

Coal in Texas.—A good hard bituminous coal is now being mined near the western border of Parker county, Texas. It is stated to be extremely free from slate and sulphur, and the proportion of ash is

* *Iron Age*, vol. xlviii. p. 61.

† *American Manufacturer*, vol. 1. p. 332.

‡ *Ibid.*, vol. 1. p. 240.

§ *Engineering and Mining Journal*, vol. liii. p. 299.

low. Coking ovens will shortly be erected, as the coal yields an excellent coke.*

The Coal of the Southern United States.—Mr. O. Barrett † gives the following assay results of coals from the properties of the Virginia and Tennessee Coal and Iron Company, the character of the coke produced from these coals being also shown:—

	Fixed Carbon.	Volatile Matter.	Moisture.	Sulphur.	Ash.
Jawbone seam . . .	53·3	30·7	0·6	0·7	14·8
Imboder seam . . .	58·5	36·8	0·4	0·6	3·7
Lower Banner seam . .	56·3	36·4	1·2	0·6	4·6
Upper Banner seam . .	64·3	31·9	0·8	0·8	2·1

The coke produced from the coal of the three last-mentioned seams contains about 93 per cent. of carbon.

Mexican Coal.—A bulletin issued by the Bureau of American Republics relates exclusively to Mexican coal deposits. Reports of the discovery of anthracite were numerous during the year 1881, and the Mexican Department of Public Works then appointed scientific commissions to visit and report on the alleged discoveries. The anthracite deposits reported on were situate in the provinces of Sonora, Michoacan, Vera Cruz, Guerrero, Oaxaca, Puebla, and other States. The fuels found assayed from 41 to 92 per cent. of carbon, the latter assay being from the State of Sonora. Near Piedras Negras, Coahuila, is a seam which has been opened up by a number of trial shafts, the fuel in sight being estimated at 9,000,000 tons of a superior quality, though it still remains unworked.

At Barranca, on the Yaqui River, Sonora, is a deposit of anthracite assaying 90 per cent. of carbonaceous residue. This occurs in sandstone and conglomerates. In the district of Justlahuaca, Oaxaca, considerable deposits of anthracite are stated to exist, and in the State of Puebla fifty-nine workings exist, though but few of them are actually being worked.

A number of other deposits are also known, and one seam, recently

* *American Manufacturer*, vol. 1. p. 333.

† *Ibid.*, vol. 1. p. 196.

discovered at the San Marcial field, Sonora, is 6 feet in thickness and only 17 feet below surface. Lignite also is found in a number of places, though it is but little used.

A Mexican official report * gives the results of the recent exploration of the coal deposits in the State of Sonora. In this State the anthracite field has been found to extend over 570 square leagues. The borings made show the seams of anthracite to vary from 2 to 25 feet in thickness. The valley of San Marcial alone is believed to contain at least sixty billions of tons of good quality coal.

Coal in Tonquin.—It is stated that considerable deposits of hard coal have recently been discovered in Tonquin, and that this coal is gradually coming into strong competition with coal from Japan.†

Coal in Honduras.—Mr. W. A. Thacker ‡ states that float coal is often found in some localities in Honduras, and that it appears to come from Carboniferous seams interstratified amongst the marly shales, but most of the specimens contain about 75 per cent. of ash. Workable coal seams may, however, be found, as strata of Permian age exist over a large part of the country. A well is being sunk near Palmyra, but no oil has been found up to a depth of 1100 feet. It is intended to sink the borehole to sea-level, a depth of 3200 feet.

Coal in Patagonia.—It is reported§ that coal has been found very near the surface in Shagnet Bay, in the Straits of Magellan. Experts from Valparaiso report that the coal is abundant and of good quality.

Coal in Turkestan.—According to a report by M. D. C. Mickenkow,|| of the Tashkend mines, no traces of coal working by the natives can be found in Turkestan. Since the Russian occupation coal-mining has developed slowly, and the annual production does not exceed 8000 tons. The beds belong to the brown Jura formation. The coal contains on an average 50 per cent. of fixed carbon, 33 per cent. of volatile matters, and 17 per cent. of water and ash. The calorific power is 4500 to 6500. The extraction is easy, and the seams vary in thickness from 7 to 18 feet. Naphtha is also found in the country.

* *American Manufacturer*, vol. I. p. 241.

‡ *Colliery Guardian*, vol. lxiii. p. 1070.

|| *Engineer*, vol. lxxii. p. 479.

† *Iron Age*, vol. xlix. p. 208.

§ *Ibid.*, vol. lxiii. p. 72.

The Lin-si Collieries, China.—According to a report of the French Consul at Tien-tsin,* the Lin-si collieries have been reached since 1891 by a branch of the Kaiping railway. These mines, like those of Tang-shan, were formerly worked by the natives, coal in sufficient quantity to supply the adjacent villages being brought up in men's arms from a shaft 120 feet in depth. Five years ago the Kaiping Company put down a borehole in this district to a depth of 300 feet. The coal obtained was found to be of good quality, and it was calculated that the deposit contained some 400,000,000 tons of coal. In 1889 workings were commenced, and a second shaft was sunk to a depth of 600 feet.

The two shafts are now furnished with winding engines, pumps, and ventilating fans, and some 100 tons per day are raised. When, however, the underground workings are extended, these shafts will be able to raise 1200 tons of coal in twenty-four hours, and it is intended to sink a third shaft equipped with the best machinery. The coal is sold at the mine at 7s. per ton.

III.—CHARCOAL.

Compressed Peat Charcoal.—H. Ekelund,† of Jönköping, utilises the heat from the cooling peat charcoal and the waste furnace heat to dry the peat preparatory to coking it, and in this way he is able to treat with advantage material too high in moisture to be otherwise employed. He gives a statement of the cost of production of such charcoal.

Experiments with the Ekelund process ‡ of making coke from peat have been carried out at Omberg, near Motala, in Sweden. The furnace or oven is built of firebrick, and is divided into four chambers, 32 feet high and 20 feet square. The peat is conveyed on rails into the top chamber, where it is dried for two hours. It is then transferred through doors into the second, and then into the third chamber, in each of which it remains for two hours, and the coking is thus performed in two stages. After this the coked peat is transferred to the fourth or cooling chamber. The gas from the second chamber is passed through condensers to the third chamber, after which it is used for generating

* *Annales des Mines*, 9th Series, vol. i. p. 265.

† *Komprimeradt Kol af Brännrotf*, Jönköping, 1891.

‡ *Colliery Guardian*, vol. lxiii. p. 432.

steam. The furnace will treat 10,032 cubic feet of peat with the production of 48 tons of coke in the twenty-four hours. The coke is either compressed or is used as produced.

IV.—COKE.

The Dry Distillation of Coal.—Mr. A. Hennin* discusses the formation of ammonia during the distillation of coal in closed retorts. The ammonia, the author observes, does not exist in the coal in this form, but its presence becomes observable when the coal is raised to a temperature of about 1800° F. The atmosphere of the retort in which the coal is being heated then contains a considerable quantity of ammonia, and the presence of this gas may be observed as long as any volatile matters are given off from the coal. The ammonia, therefore, is a secondary product of the distillation, and is formed when the nitrogen meets the hydrogen in its nascent state, or when both meet under these conditions.

Nitrogen exists in coal in the proportion of $1\frac{1}{2}$ or 2 per cent., probably as one of the constituents of various organic compounds. A distillation of the coal made below a red heat does not cause the formation of ammonia. The author considers that the hydrogen which enters into combination with the nitrogen is not that existing in the coal in combination with carbon, nor that which is due to the presence of hygroscopic moisture. He considers that it is due to the presence of water of combination, which vaporises only when the decomposition of the coal is far advanced. To increase the percentage of the nitrogen converted into ammonia on the coal being distilled, the use of steam has been suggested, and applied with success, up to 50 or 60 per cent. of the nitrogen being then convertible into ammonia.

Drawing and Loading Coke.—Mr. C. M. Percy† describes a plant in operation at Thorncliffe, Sheffield, for drawing coke-ovens and loading the coke. The extractor runs on rails, and consists of a shovel device, which is mounted on an arm angularly adjustable by hand-gearing, and worked by steam power through a rack and pinion. Sufficient space is left between the ovens and the machine for a travelling belt, which takes the coke to the elevators. The coke is gently

* *Iron Age*, vol. xlviii. p. 1152.

† *Colliery Guardian*, vol. lxii. p. 893.

dropped from the elevator buckets on to the screens by a drum revolving in the opposite direction to the elevator. The drum is divided by partitions corresponding to the elevator buckets.

Improvements in Coke Ovens.—F. W. Lürmann * describes, in a paper read before the Institution of German Ironmasters, the more modern improvements in coke-ovens and in the arrangements for the collection of the by-products. These latter are not simple, and require careful looking after. Their use, too, causes a considerable increase in the first cost of the oven. Still, such ovens have rapidly come to the fore, as is shown by the following figures :—

Hoffman-Otto Coke Ovens.

Years.	In Use.
1884	40
1885	210
1889	605
1892	1205

These figures refer to the use of this coke oven in Germany alone. The cost of a battery of sixty such ovens, with all arrangements for the collection of the by-products, including machinery duplicates, is £36,000. Of this sum £15,000 is the cost of the ovens, and £21,000 that of the condensing plant. The charge for an oven is in Westphalia $6\frac{1}{4}$ tons of dry coal, the operation of coking lasting forty-eight hours. A group of sixty ovens treated in Upper Silesia 70,200 tons of coal in the course of a year. The yield of products from the coal coked has been as follows in the districts named :—

District.	Coke.	Tar.	Ammonium Sulphate.
	Per Cent.	Per Cent.	Per Cent.
Ruhr	75-77	2.5-3.0	1.1-1.20
Upper Silesia	65-70	4.0-4.5	1.0-1.25
Saar	68-72	4.0-4.3	0.8-0.90

The quantity of gas produced, and used by this oven, is shown in the following table, which gives the quantities per oven per day :—

* *Stahl und Eisen*, vol. xii. pp. 186-195.

District.	Gas Produced.	Gas Used.	Excess.
	Cubic Feet.	Cubic Feet.	Cubic Feet.
Ruhr	35,317	21,190	14,127
Upper Silesia	40,614	22,956	17,658
Saar	35,317	21,190	14,127

It is calculated that 18·3 cubic feet of gas is equal to one lb. of coal burnt under the boilers.

Semet-Solvay Oven.—This oven consists of a horizontal chamber with horizontal side-flues. The roof is very thick, and this is stated to greatly retain the heat, and to enable, owing to the hot working of the oven, mixtures of 73 to 77 per cent. of bituminous coal, and 23 to 27 per cent. of non-caking coal to be coked successfully. In Germany 24 of these ovens are erected at the Phoenix steelworks, near Ruhrort. They are working on the above mixture, and it is found that 32 ordinary coke-ovens are required to do the same work as these 24 modified ones, the two being erected side by side and open to direct comparison. A second battery is about to be erected at these works. At the Havré colliery, near Mons, 100 of these ovens coke in twenty-four hours 115 4-ton charges. The 24 ovens at the Phoenix works coke per month 3285 tons of the coal mixture, producing 2546 tons of coke, and also 22 lbs. of tar, and 16·8 lbs. of ammonium sulphate per ton of coal charged. Within the last three years benzine has been condensed direct from the coke-oven gases. The necessary additional plant for this purpose costs £250 per oven.

The author next proceed to discuss the commercial side of the question of the condensation of the by-products, and he calculates the profit so derived in the case of the Hoffmann-Otto oven at 3s. 9d. per ton of coke made. A lengthy discussion followed on the reading of this paper.

The Semet-Solvay Coke-Oven.—M. C. Demanet * states that the first ovens on this system were erected in 1882 at the Belle-Vue pit No. 2, belonging to the Ouest de Mons colliery. Six ovens were at first erected, and another 25 were then constructed by the Solvay Company. At the Havré colliery four sets of 25 ovens each are now in use. In principle the oven resembles the Coppée, with modified

* *American Manufacturer*, vol. 1. pp. 318-319, with illustrations.

side-channels, and with an arrangement for the condensation of the by-products. The inside dimensions of the oven are:—Length, 30 feet; breadth, 1 foot 2 inches on the side of the steam-ram used for ejecting the charge, and 1 foot 3 inches at the other; the height is 5 feet 8 inches. The brick walls are two bricks thick (16 inches), and the thin sides of the tiles or retorts 3 inches. The heating flues are independent of the walls and arches of the ovens. The cost is about £160 per oven, each oven having a monthly capacity of about 100 tons of coke, the charge per day being four tons and the coking being complete in twenty-two hours. The coal obtained at this colliery is often much crushed, and sometimes only contains 16 to 17 per cent. of volatile matter, but, as a rule, the average is between 18 to 23 per cent. The coal is broken in Carr's disintegrators and part is washed on a Bérard washing-floor if required. The gas from each set of ovens is drawn off by a Beale exhauster, and passed through condensers and scrubbers. Part of the gas is used in the boilers, of which there are two to each bench. The ovens are heated by the gas which is burnt in the flues with air heated to 200° to 300° C. by passing it under the floors of the ovens. A sketch of the plan of the works and of the construction of the ovens are given.*

Coke from the Silver Hill Colliery.—An assay, given by Mr. J. C. B. Hendy,† of the coke from the Silver Hill Colliery shows:—

Molsture.	Carbonaceous Matter.	Sulphur.	Ash.	Total.
0·70	85·86	1·34	12·10	100·00

The coke is made from black shale small washed in a 5-ton Robinson washer mixed with twice the quantity of Low Main small. There are sixty-two ovens, 12 feet in diameter by 7 feet high.

Kanawha and New River Coke, Virginia.—An estimate has been given of the cost of producing coke in these districts of Virginia. The estimate is as follows:—

	Dollar.
1·6 ton of coal @ 55·8 cents	0·8925
Cost of coking	0·3600
General expenses	0·0500
Royalty, 15 cents. per statute ton	0·1340
Total per ton of 2000 lbs.	1·4365

* *Colliery Guardian*, vol. lxiii. pp. 149-150.

† *Transactions of the Federated Institution of Mining Engineers*, vol. ii. pp. 550-551.

In the New River district there are 859 ovens, with a monthly capacity of 26,210 tons, and in the Kanawha district 474 ovens, with a monthly capacity of 16,850 tons. The largest plant in these districts is that of the Mount Carbon Company, Kanawha, with 202 ovens in work.*

Coke in Eastern Kentucky.—The coals and cokes of Eastern Kentucky are described by Mr. J. H. Allen,† a short account of the other American coke-producing districts being given in comparison. The Pocohontas seam is the same as the Quinnesmont bed in the New River district, and it covers a district sixty miles long by sixteen miles wide. In 1882 there were 200 coke-ovens, but by 1890 the number had increased to 1884 ovens in use, with over 900 building or to be built. This coke is used in fourteen furnaces in Virginia. The Eastern Kentucky field embraces an area of 10,000 square miles, or one-seventh of the entire Appalachian field, and contains six workable seams above water-level. An assay of the Pineville coke by Mr. J. Fulton shows—

Fixed Carbon.	Moisture.	Ash.	Sulphur.	Phosphorus.	Volatile Matter.
94·66	1·14	3·37	0·59	0·007	0·041

The weight per cubic foot is 52·75 lbs. dry, or 84·73 lbs. wet ; hardness, 3 ; specific gravity, 1·71. Another assay gives—

Moisture and Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
0·40	95·89	3·71	0·63

The two seams worked at Pineville are 36 and 54 inches in thickness.

The Manufacture of Anthracite Coke.—In the course of a discussion‡ at the Glen Summit meeting of the American Institute of Mining Engineers on the utilisation of small sizes of anthracite, Mr. F. M. F. Cazin stated that he was the first to utilise anthracite waste in Germany in 1854, by mixing it with the smalls of bituminous coking coal, and treating the mixture in coke-ovens.

Mr. T. Straker, giving an account of some experiments on a small scale on the coking of anthracite waste mixed with bituminous slack, reported that while the bituminous coal alone gave a good ordinary coke, and the anthracite alone gave no sign of coking, he obtained

* *American Manufacturer*, vol. 1. p. 332.

† *Transactions of the American Institute of Mining Engineers*, Baltimore meeting (advance proof).

‡ *Ibid.* (advance proof). The manufacture of anthracite coke in Wales was exhaustively dealt with in 1875 at the Manchester meeting of the Iron and Steel Institute.

from a mixture of equal proportions fair coke, and from three-quarters anthracite and one-quarter bituminous coal a silvery hard coke.

Dr. R. W. Raymond gave the results of some experiments made by Mr. F. Platt, which included coking with and without the addition of pitch, and with varying proportions of anthracite and bituminous coal. It was found that a fuel could be made which would answer the purposes of ordinary coke. The use of pitch has little, if any, advantageous effect. Anthracite coke can best be made in long, narrow ovens, and the best mixture is half anthracite and half bituminous coal. The best coke made in these experiments contained 9·985 per cent. of ash.

The Cost of Production of Coke in the United States.—Mr. C. D. Wright, United States Commissioner of Labour, reports * that the average cost of mining bituminous coal in the United States is as follows :—

Elements of Cost.	Run of Mine.	Lump.
	Dollar.	Dollar.
Labour	0·648	0·933
Officials and clerks	0·017	0·042
Timber	0·015	0·026
Other supplies and repairs	0·042	0·050
Taxes	0·006	0·007
Totals	0·728	1·058
Value of screenings	...	0·133
Net total	0·728	0·925
Quantity, tons of 2000 lbs.	7,446,253	5,563,547

Details are given in the report which relate to the cost of production of 2,036,183 tons of coke made from 3,166,308 tons of coal. The average cost of making the ton of 2000 lbs. of coke is as follows :—

	Dollar.
Coal for coking (3110 lbs.)	1·219
Labour	0·357
Officials and clerks	0·028
Supplies and repairs	0·058
Taxes	0·005
Total	1·667

* *Iron Age*, vol. xlviii. p. 924.

V.—LIQUID FUEL.

The Origin of Petroleum.—In his recent work on "Systematic Mineralogy," Dr. T. Sterry Hunt * gives a clear summary of the leading hypotheses with regard to the origin of petroleum. Whether the origin be animal or vegetable he regards as an idle question. When it is considered that the albumenoids of plants and of animals are the same, that the fatty bodies are for the most part identical, that glycogen, so abundant in the liver and other tissues of the higher animals, is isomeric with starch, and that tunicin, which is found in the mantle of Ascidians, is similar in composition to cellulose, the question loses its significance. To the chemist there is in ultimate analysis no difference between the composition of oats and the body of the animal daily fed on that substance.

Professor Stickenberger † gives an account of the present formation of petroleum in the Red Sea. Here there is a superabundance of animal life, especially of the lower orders. As there are not sufficient scavengers to remove the dead bodies, they decompose and give a heavy brown oil with the evolution of sulphuretted hydrogen. The action is favoured by the heat and the saltiness of the water. The oil is absorbed by the porous rocks. The asphalt in the Dead Sea is referred to as showing that similar conditions formerly existed there.

The Petroleum Industry of Galicia.—The rise and progress of the petroleum industry of Galicia is traced in great detail by Mr. B. Redwood, ‡ and mention is made of the localities in which oil is found in this and in the adjoining districts. The oilfields lie in parallel lines with the mountain ranges, which run from north-west to south-east, and the oil is found in beds of the Miocene, Eocene, and Cretaceous ages. In shallow wells the oil is of greater specific gravity.

Oil is obtained either from drilled wells or from excavated shafts. The wells were formerly made by the free fall system, but recently the Canadian system has been successfully adopted. The diamond system has scarcely been used. The oil does not flow from the wells, but has to be pumped, and the production at the present time only amounts to half the consumption. The oil produced is refined in the

* *Systematic Mineralogy, Based on a Natural Classification*, New York, pp. 333-343.

† *Chemiker Zeitung*, vol. xv. p. 87.

‡ *Journal of the Society of Chemical Industry*, vol. xi. pp. 93-119.

district. Besides petroleum, ozokerite is largely produced by crude methods of working.

Petroleum and Natural Gas in Italy.—The petroleum industry in Parma is described by the Belgian Consul at Lucca.* Petroleum was here discovered at the beginning of the century, and the productive ground covers a considerable area. Up to the present the production has been limited. One well, 157 yards deep, yielded 280 tons between 1886 and 1890. Lately, deeper wells have been sunk. Natural gas is found in some of these wells, and is used for lighting and heating. Salsomaggiore is entirely lighted by this gas.

Acids in Petroleum from Baku.—O. Aschan† describes the occurrence in Baku petroleum of acids of the formula $C_nH_{2n-2}O_2$. One of these, $C_8H_{14}O_2$, boils at 237° , and from this the author obtained the hydrocarbon C_8H_{16} . The acid $C_9H_{16}O_2$ boils between 251° and 253° . Its calcium and barium salts are not decomposed by carbonic acid.

Petroleum in North Alabama.—A review of the occurrences of natural gas and petroleum in North Carolina is given by Mr. H. McCalley.‡ Scattered over the country are a number of tar springs in the outcrops of the Carboniferous and Sub-Carboniferous formations. Wells have been bored in these strata, but the records of them are only fragmentary. In 1865 two wells are said to have yielded oil. Last year a well sunk in the Moulton Valley struck gas at several levels, and also two layers of oil when the Trenton measures were reached, but the oil was drowned out. A large number of wells have been or are being bored, oil and gas being found in some, but apparently not in any quantity. An interesting occurrence of oil is found near Guntersville, in the Knox dolomite, where it exists in cavities in quartz crystals. In conclusion, the author does not think that oil or gas in large quantities will ever be found in this district, at least in the Palæozoic rocks, as they are so greatly disturbed. Sections of some wells are given.

The Florence Oilfield, Colorado.—The Florence oilfield in

* *Iron*, vol. xxxviii. p. 542.

† *Berichte der Deutschen chemischen Gesellschaft*, vol. xxiv. p. 2710.

‡ *Proceedings of the Alabama Industrial and Scientific Society*, vol. I. pp. 35–43, one plate.

Colorado, described by Mr. G. H. Eldridge,* is in the valley of the Arkansas River, close to the eastern base of the Rocky Mountains. Active exploration was begun in 1862, but oil was only found near the surface in the early borings. Since then, oil has been found at greater depths, and is being worked by four companies and by individual enterprise. The field is confined within the limits of a synclinal basin, elliptical in area, and fourteen miles long by eight miles wide. The strata found in the field or in the neighbourhood range from the Archean up to the Tertiary age, but the formations of most interest are the Cretaceous, comprising the Dakota, the Benton, and Niobrara, constituting the Colorado group; Pierre and Fox Hills constituting the Montana group and the Laramie. Details of the strata in these formations and their thicknesses are given. The Montana group is about 4900 feet thick, of which the Pierre occupies about 4450 feet. This latter formation is chiefly one of argillaceous shales, with local developments of sandy strata from which the oil appears to come. The sandy parts are found either as lenticular patches or as sandy variations of a more argillaceous bed. The thickness of the oil-bearing zone has not yet been determined, as there are but few borings deeper than 2000 feet. Some productive borings have been made on the outskirts of the present field, and there appears to be no reason why it should not be found to extend over a considerable distance. It seems probable that both the source and the reservoir of the oil is to be found in the Pierre formation itself, as no system of fissuring and supply from other beds can satisfactorily explain its presence, and most of the wells remain dry after exhaustion. From the nature of the formation, the continuity of the oil-bearing characteristics of this formation cannot be relied upon. Within a distance of 1155 feet below the summit of the oil-bearing zone no unproductive measures exist of a thickness greater than 100 feet if the field be taken in its entirety, though barren areas of greater thickness are found in isolated areas. No connection exists for the field in general between flows of the same horizon. In a single instance only has a new well influenced another at a greater distance than 200 feet, and wells within 25 feet of one another often have no mutual effect. This is to be explained by the rapid alteration in the lithological character of the beds. Up to November 1890 there were altogether 82 wells in the Pierre formation. Of these, 16 per cent. have shown no trace of oil, 19½ per cent. show only traces of oil, in 7

* *Transactions of the American Institute of Mining Engineers*, Glen Summit meeting (advance proof).

per cent. the yield is less than 5 barrels, and 57½ per cent. have been successful. Some wells have yielded as much as 150 barrels daily, but the production gradually declines, the decrease lasting in some cases for several years. Torpedoes do not appear to have any useful effect on the well. Gas occurs chiefly with the oil, seldom by itself, and water has only been met with in a few wells in the oil horizon. The oil itself is a light yellowish green, averaging 31° B. in density, and remarkably free from impurities. The present production averages 2000 barrels daily. The author can form no opinion as to the origin of the oil.

Petroleum in Pennsylvania.—A new oil region, which has been named the M'Donald field, has recently been opened up in Pennsylvania. Its yield already amounts to 52,000 barrels daily. Within so short a period as ten months this field has produced over 2,500,000 barrels of oil, valued at 2,000,000 dollars. The pipe lines laid are so little able to carry the yield of oil that it is estimated that in ten weeks 100,000 barrels of oil was lost.*

The outflow of oil in this field is stated to be of unprecedented magnitude. Thus the largest previous record related to a well at Cherry Grove, which in 1882 gave an output of 40,000 barrels for a few days only. The M'Donald well has yielded 3,000,000 barrels in a little over a hundred days.†

Naphtha Deposits in Persia.—Mr. J. de Morgan‡ gives a detailed description of the naphtha deposit of Kend-é-Chirin in the government of Seri-poul. This deposit occupies the centre of a zone of petroleum springs, and is situated within fourteen miles of the Turkish frontier. Small veins of ozokerite met with, though not of industrial importance, are regarded as a valuable indication of the importance of the naphtha deposits.

The deposits have been worked on a small scale since very ancient times. A trench 6 yards long, 8 yards deep, and 3½ yards wide at the bottom has been dug by the Kurds. Two small shafts 9 yards in depth have also been sunk. Salt water and naphtha accumulate in these two shafts, which are emptied every four or five days. Each operation gives fifty-five gallons of crude oil and a large quantity of salt water. The shafts are emptied by means of a rope and bucket,

* *Iron Age*, vol. xlviii. p. 723.

† *Ibid.*, vol. xlviii. p. 762.

‡ *Annales des Mines*, 9th Series, vol. i. pp. 227-238.

the naphtha being placed aside in a cavity prepared for its reception, and the salt water being emptied into evaporating pans. Ten or twelve men are engaged in the work, and receive eightpence per day each. The crude oil is transported on mule-back to Kasr-é-Chirin, and is there refined. The crude oil is very liquid, has a green colour, and possesses a very strong odour. The pits sunk by the Kurds are only on the outcrop of the deposit, and do not reach the impermeable rock on which it rests.

Petroleum in Assam.—The Assam Railway Company has been boring for petroleum on the property of the company, and it is stated * that oil had now been found in quantity at a depth of 650 feet. The well is yielding at the rate of 700 barrels of oil a day.

Peruvian Petroleum.—C. Ochsénus † describes the occurrence of petroleum in the department of Piura, Peru, between Payta and Tumbes. The oil has to be pumped. The bore-holes sunk number twenty-eight, and they vary from 50 to 260 yards in depth. The daily output of oil is about 2000 barrels. At the commencement a well will yield between 3000 and 4000 gallons of oil a day. The oil has a specific gravity of 0·868, and its composition has been variously stated as follows :—

	C.	H.	O.
I.	84·9	13·7	1·4
II.	75·8	18·4	5·8

The oil occurs in a Tertiary formation. Salt and coal occur near the oil. Other places in Peru are named at which petroleum has been met with.

VI.—NATURAL GAS.

Natural Gas in Utah.—For years past the presence of small quantities of natural gas has been observed in connection with the flow of water from artesian wells near Salt Lake City. These wells are usually less than 200 feet in depth with a 2-inch pipe. In but one instance was the gas collected utilised—in heating a cooking stove—and this gas has been so burned for the last five years. A well has recently been sunk to a depth of 420 feet, at a distance of some thirteen miles from Salt Lake City. It has 6-inch piping. It is thought that

* *Globe*, February 11, 1892.

† *Chemiker Zeitung*, vol. xv. p. 1866.

a black shale rock was reached, and then gas was struck in volume, and at a pressure of 150 lbs. Another well, distant fifty feet from the former, is 180 feet in depth, and yields gas at a pressure of 100 lbs.*

VII.—ARTIFICIAL GAS.

Anthracite Waste in Gas-Producers.—A low estimate of the waste from anthracite thrown on the spoil banks in Pennsylvania alone places the quantity at over sixteen and a half million tons, whilst thirty-five and a half million tons were marketed in the same year 1889. As gas-producers have been utilised for burning up all sorts of waste, Mr. W. H. Blauvelt † made some experiments in the direction of using fine anthracite in the Taylor gas-producer. In this producer a solid circular plate takes the place of the ordinary grate, and the fuel is supported on a deep bed of ashes. But insurmountable difficulties were met with in the use of the fine waste, as the air would not properly distribute itself. Either it went up near the walls and caused excessive local heat and clinkering, or else the fuel-bed had to be so thin that practically no carbonic oxide was produced, or the rate of production was so small that it was not economical. Experience shows that the best size to use is that known as “No. 1 Buckwheat” and “Pea,” and much of this size, or even larger, might be found in the older culm heaps, but the profitableness of its recovery is doubtful. Fine anthracite can be used in considerable quantities when mixed with sufficient bituminous coal to keep the fuel-bed open, but the mixture even then only works indifferently, and the bituminous coal is expensive in anthracite districts. When the cost of carriage is large, the large percentage of ash in the culm makes its use of doubtful value as compared with properly prepared buckwheat, apart from the difficulties of gasification as shown by evaporation experiments under boilers. The only way at present is to separate the larger sizes as thoroughly as possible, and to leave the culm for utilisation by other processes in which it may prove to be available.

Gas-Producers.—The theory of the gas-producer and its history are sketched by Mr. R. Booth, ‡ the advantage of gaseous fuel being

* *American Manufacturer*, vol. 1. p. 69.

† *Transactions of the American Institute of Mining Engineers*, Glen Summit meeting (advance proof).

‡ Paper read before the Society of Civil and Mechanical Engineers, February 17, 1892.

also pointed out. Analyses of producer-gas are given and the working of producers is discussed, attention being paid to the methods of introducing the fuel, and especially to the question of the blast. The Wilson producer and the various improvements on it are described, and also the method of continuous working devised by Mr. Dawson. The difficulties arising from clinker are dealt with, and the various means of overcoming them. An advance on former methods for this purpose is in the use of the Dawson water-bottom. Forced draught and slow combustion are compared, to the advantage of the former. Deficiencies in the economy of the producer-gas system are discussed, particularly the question of radiation from the producers and from the gas mains. These losses have, as a general rule, been much exaggerated, and any difficulties in the working generally arise from bad design. In conclusion the author points out the general advantages arising from the use of fuel gas instead of solid fuel.

Mixed Producer-Gas.—Mr. A. Hennin* gives the following analysis of a mixed producer-gas obtained from a bituminous coal, a mixture of air and steam being blown into the producer:—

	Per Cent.
Carbonic oxide	20·0
Carbonic anhydride	10·5
Methane and homologues	4·5
Hydrogen	38·0
Nitrogen and oxygen	27·0
Total	100·0

About 150,000 cubic feet of such gas are produced from the ton of coal, in addition to 17 to 20 gallons of tar.

The Lencauchez gas-producer, which was fully described in the last volume,† is criticised by Bonneville.‡

Production of Water-Gas.—In an exhaustive paper on this subject, Shelton§ states that the plant used for the production of water-gas may be divided into two classes:—(1.) Systems with retorts, in which the steam is conducted into retorts filled with coal, the temperature of the retorts being maintained by external heating. Examples of this class are afforded by the apparatus of Milton, Sander,

* *Iron Age*, vol. xlviii. p. 1153.

† *Journal of the Iron and Steel Institute*, 1891, No. II. p. 197.

‡ *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1892, pp. 26-28.

§ *Dingler's Polytechnisches Journal*, vol. cclxxxi. p. 65.

1892.—i.

Allen-Harris, Salisbury, and Jeczmanowski. (2.) Systems with producers, in which the steam is conducted into retorts or producer shafts filled with coal, the heating being effected in the interior by the partial combustion of the fuel. This class may be subdivided into (a.) methods in which a non-illuminating gas is produced with subsequent carburisation, as in the apparatus of Jeczmanowski, Tessié du Motay, Wilkinson, Harkness, Harton, Edgerton, Mackenzie, Egner, and Meeze, and (b.) methods in which production and carburisation are effected in one appliance, as in the apparatus of Lowe, Springer, Flannery, Kay, Crithlow, Martin, Pratt-Kyan, Steenburg, and Loomis.

VIII.—COAL-MINING.

Rope-Boring.—A. Arlt* describes an application at Teplitz, in Bohemia, of the American system of boring by the aid of ropes. Here a bore-hole 8 inches in diameter has been sunk, mainly in porphyry, to a depth of 1233 feet by this method. A bore-hole previously put down by the ordinary method had got out of plumb at a depth of 72 feet.

Boring through Quicksands.—R. A. Monet† gives an account of an exploratory boring for coal made near Lallaing in the concessions of Aniche and Escarpelle. The strata passed through near the surface were:—Soil, $2\frac{1}{2}$ feet; running and other sands, 47 feet; clay, 36 feet; and then the chalk, which contained a large amount of water. To stop out this water, and to prevent it washing away the sides of the upper part of the bore-hole, two concentric tubes were sunk in the hole into the clay before the chalk was reached, and the space between these tubes was filled with cement. The outer tube was 26 inches in internal diameter, and the inner tube, 21·6 inches in external diameter, was sunk $7\frac{1}{2}$ feet deeper than the outer one. A mixture of hydraulic cement and sand was then used to fill the space between the tubes. After the chalk was reached a length of 10 feet of tubing had to be fixed over the bore-hole, to prevent the water overflowing, and the boring proceeded through this till a depth of 157 feet, when a third tube of 15·75 inches in diameter was sunk, and the exterior space again filled with cement. This reduced the flow of water so that the 10 feet of tubing above the surface could be removed.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. pp. 453-456, eleven illustrations.

† *Société de l'Industrie Minérale, Comptes Rendus*, 1891, pp. 233-237, one plate.

Rapid Shaft-Sinking.—A shaft 12 feet by 26 feet has recently been completed to a depth of 385 feet in connection with the Oliver coke-works of Pittsburgh. The work was begun on June 21, 1891, and the sinking occupied twenty-one weeks five days. The average rate sunk per week was thus 17·7 feet. In the first six weeks only 30 feet was sunk, but during the last sixteen weeks the average rate reached 3 feet 9 inches per working day. The timbering was put in as the work of sinking progressed, so that the record is for the shaft complete with the timbering in place. Ingersoll drills were used.*

Sinking Shafts through Quicksands.—A description is given by Mr. T. C. Hair† of the methods employed for sinking through 32 yards of quicksand at the Ryhope colliery, Durham. Though the pit was sunk some thirty-three years ago, no account appears to have been published. Two wedging cribs were put in when the sinking had proceeded in the limestone to within six yards of the sand, and from these the tubbing was hung. Inside flanges were used on the tubbing to allow additions to be made at the bottom when possible. Large segments of boiler plate projecting a foot or more were placed between the joints to form shelves to prevent the sand sliding down. The method of putting the segments in position and of suspending the tubbing is described.

A description is given by Mr. R. Clough‡ of a successful sinking at Lingard Lane colliery, near Stockport, through six unexpected beds of quicksand in the first fifty yards. In going through these quicksands a small drum was sunk in the centre of the shaft through the sand and into the marl below. The sand from the exterior was thrown into the drum, from which it was wound by a water-tub until a foundation for coffering could be made. In the top quicksand, 90 per cent. of the water was pumped from a staple sunk specially to drain this bed. The sand was kept from running into the shaft by piles driven behind the brickwork and packed outside with straw or like material. The method of sinking and dropping the pumps is fully given by the author.

Some notes on the sinking at the No. 10 pit at the Lens colliery by the Poetsch system are given by Mr. N. R. Griffith.§ The shaft is

* *American Manufacturer*, vol. I. p. 241.

† *Proceedings of the South Wales Institute of Engineers*, vol. xvii. pp. 242-246.

‡ *Journal of the British Society of Mining Students*, vol. xiv. pp. 106-113, illustrations.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. ii. pp. 441-443, one plate. See *Journal of the Iron and Steel Institute*, 1891, No. II. p. 201.

15 feet 9 inches in diameter, and twenty-eight bore-holes have been put down for the freezing pipes. Plans and elevations are given to show the disposition of the pipes about the shaft.

Winding and Hauling Plant at the Bascoup Colliery.—A detailed account is given by Mr. H. W. Hughes * of the winding and hauling plant at the No. 5 pit of the Bascoup colliery, Belgium. A plan of the surface shows three shafts, of which one is used for winding, the output being 1100 tons per day. Vertical winding-engines and cylindrical drums are used. The cage is attached to the rope by seven bridle-chains, the central one being connected to the cage by a spring buffer to take the shock of starting. The bridle-chains are made very long, and, with the aid of a balance platform at the bottom and Stauss props at the top, the changing of the tubs is done very rapidly. The Stauss props, which are fully described, by an arrangement of levers and by the form of the keps hold the cage firmly, but yet can be withdrawn while the full weight of the cage is resting on them, so that the engine does not have to be reversed. Rail guides supported by H steel girders are employed. The descent and ascent of the men is effected in a separate shaft by means of double-acting man-engines. An elaborate system of endless chain haulage has been installed. Full illustrations are given of all the special features described.

Modified Koepe System of Winding.—The Koepe system of winding, but in a modified form devised by M. de Mot, has been adopted at the Moulin pit, Gilly, Belgium.† The pit is to be deepened to 940 yards, but it now has insets at four levels ranging from 180 to 855 yards. The output is 300 tons of coal daily with 75 tons of dirt. A six-deck cage for six tubs is used, the cage and tubs weighing 3·7 tons. The Koepe system has been adopted; only two ropes are used instead of one. Each rope passes round its own groove on the drum and pit-head pulleys, their ends being connected to the cage by chains, so that one rope could support the cage if the other broke. Each rope has a factor of safety of six by itself, and the high safety is thus attained at a less cost than it would be by a single rope. In addition, the crushing effect on the lagging of the drum is greatly reduced. The drum is made from one of the original flat rope reels by fitting it with

* *Journal of the British Mining Students*, vol. xiv. No. 3.

† *Annales des Travaux Publics de Belgique*, 1891, p. 465; *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cvii. pp. 523-525.

a rim originally 23 feet in diameter, but subsequently reduced to $16\frac{1}{2}$ feet. It was lined with grooved beech blocks 7·8 inches thick, the grooves being 7·8 inches apart and 1·6 inch broad. Horizontal winding-engines are used. The steel wire ropes are 1·61 inch in diameter, with eight strands containing 19 wires of 0·866 inch diameter, and having a tensile strength of 87·6 tons per square inch. The balance ropes below the cages are of galvanised wire, with a tensile strength of 45 to 50 tons per square inch. This system has been in successful use since August 1889.

Electricity at the Aspen Mines.—The Aspen Mining Company of Colorado was the first to apply electric power for winding in America, the plant having been in successful operation since July 1888. An interesting record of what has been accomplished by this company is given by Mr. M. B. Holl.*

The ore is reached by a cross-cut adit level, and two inclines following the vein have been driven below the adit level. Power for winding on these inclines is obtained from a 50-horse-power 500-volt constant potential Edison dynamo, driven by a 5-foot Pelton wheel, with an effective head of 63 feet, placed 6000 feet from the mouth of the adit. The winding-engine at the inner end is a $7\frac{1}{2}$ -horse-power Sprague motor driving two drums, one for the incline and the other for the tail-rope drawing the empty trucks back into the mine, the loaded train running out by gravity. The working of this motor proved so successful that a similar one was placed at the head of the incline, 300 feet to the north-east. Each motor is designed to raise 250 tons up a 60° incline every day of sixteen working hours. The cost of repairs of the first motor during three years' constant work was £41. In 1889 the company erected a generating plant with a capacity of 100 electrical horse-power produced by two 50-horse-power Thomson-Houston motor-type dynamos, wound for a constant potential of 500 volts. Each dynamo is driven by two double 42-inch Pelton water-wheels. A pressure of 35 lbs. per square inch is obtained from an effective fall of 80½ feet. The requirements calling for greater or less power are met by deflecting the nozzles, which work on a ball-and-socket joint, by means of a Woodward governor, and the wheels are enclosed in an iron hood. After three years' use under the varying conditions of mining work, the electric current of 500 volts has proved to be free of danger to life, and has caused no inconvenience further than one or two severe shocks.

* *Transactions of the American Institute of Mining Engineers* (advance proof).

Winding-Engines.—With the aid of numerous illustrations, Professor H. Undeutsch * describes a number of improvements in connection with winding-engines for mines. The various detaching hooks, safety catches, means of connecting the cage to the winding-rope, the winding-ropes, the pit-head gear, pulleys, drums, winding-engines, and boilers are described in detail.

Faivelay † describes a winding-engine which has been constructed at the Creuzot works of Schneider & Co. It has a cylinder diameter of 31½ inches with 62·9-inch stroke. It is designed to raise 1000 tons of coal from a depth of 656 yards during each shift of eight hours. Various improvements have been made in the construction of this engine, especially in the arrangement of the bed-plate and valves.

Electrical Safety Apparatus for Cages.—A description of an electrical safety apparatus for mine cages is given by Mr. J. Yates. ‡ The requirements of a safety apparatus are that it should never fail to act when required, and that it should not act unless the rope breaks; it should allow of being tested, it should be simple, and should not interfere with ordinary work. The apparatus consists of weighted levers, which are normally held out of action by horse-shoe magnets, but which grip the guides through the medium of cams when liberated. A continuous current is used to keep the magnets excited, and this current is led to the magnets by two copper wires laid in the hemp core of the winding-rope. The connection between these conductors and the battery is made by two brushes working on two copper rings on the drum shaft. This method of conveying an electric current to the cage has been successfully in use for some years for signalling purposes in the Durham district.

An illustration is given § of a winding indicator worked by worm gearing from the drum shaft. Electric contacts are arranged on the dial, so that the pointer completes an alarm circuit when the cage is near the end of its travel, and thereby sounds an alarm-bell. As the cage descends, the pointer lifts a spring and avoids making contact. The contact pieces are clamped in position by set screws, so that their position can be adjusted to suit the winding.

* *Civil Ingenieur*, vol. xxxvii. pp. 573–606.

† *Bulletin de la Société de l'Industrie Minérale*, vol. v. p. 479.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. ii. pp. 362–368, three plates.

§ *Electrical Review*, vol. xxix. p. 609.

Failure of Winding-Ropes in the Dortmund District.—

Nearly the whole of the winding-ropes used in the Dortmund district are of cast steel wire. In 1890, 187 round ropes and 45 flat ropes were renewed. Ten of the flat ropes and 19 of the round ones had been in use for less than 200 days, while nine of the round ropes had lives exceeding 1000 days. Only six of the flat ropes lasted more than 400 days and none more than 1000 days. Of the five ropes which broke in 1890 four were flat ones.*

Preserving Wire Ropes.—For the purpose of a protecting coating for wire ropes which are laid on the ground or which come in contact with water, a mixture of thirty-five parts of slaked lime and sixty of tar is recommended.† This mixture is boiled and the rope painted with the hot mixture. Linseed oil and vegetable tar or grease with graphite form good paints for dry-lying ropes.

A New Use for Old Ropes.—A new use for old winding-ropes is described by Mr. R. M'Laren.‡ At No. 1 pit, Gilmerton, Mr. H. Burt has used these ropes instead of rails on an incline dipping from 65° to 72°, and 96 yards long, with eight stopping-places. The road averages 12 feet wide by 4½ feet high, and has a carriage and a back-balance way. Sleepers 9 feet by 8 by 3 inches are laid across every 4 feet, and on these are fixed planks 6 inches broad by 3 inches thick, to which the ropes, 3 inches in diameter, are spiked every 8 feet. The rope is tightened up by a screw tension device before it is spiked in place. The gauge for the tub-carriage is 4½ feet, and for the balance 1 foot 10 inches. The wheels are grooved 1 inch deep. The loaded carriage weighs 13 cwt., and the time of the journey is twenty seconds. The balance consists of a plank on four wheels loaded to the required weight, and, as it is not sufficiently heavy to take the carriage up the reduced gradient, there is a second balance which rests against a block and is picked up by the first balance as it ascends and is left as it descends. Illustrations of the devices are given.

Signalling in Mines.—A new form of electric bell for signalling in mines has the striking-hammer suspended in the centre of a flexible metallic diaphragm, which allows it to move freely and does away with

* *Glückauf*, vol. xxviii. p. 25.

† *Ibid.*, through the *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 506.

‡ *Transactions of the Mining Institute of Scotland*, vol. xiii. pp. 299-305.

all pivots or springs. The actuating mechanism can thus be hermetically sealed in. A push is also made on a similar principle, so that dust or damp cannot get at the working parts.*

Endless Rope Haulage.—The endless-rope system of haulage, which has displaced the single-rope system at the Mitchell Main colliery, is described by Mr. T. W. H. Mitchell.† At this colliery the Barnsley bed is worked on the long-wall system, at a depth of 307 yards. The engine is placed on the surface and runs at nineteen to twenty revolutions per minute, and drives the rope at about fifty yards per minute. The rope is $1\frac{1}{2}$ inch in diameter, and is wrapped three and a half times round a taper drum $9\frac{1}{2}$ feet in diameter. Trucks are attached to the rope by chains 12 feet long, one end being hooked to the drawbar and the other end wrapped twice round the rope, and the hook brought across the chain when extended. Catches and means for returning the vehicles to the rails are fixed every few yards, and a guide-rail is fixed between the two tracks to prevent the full trucks from fouling the empties. Illustrations are given of the general arrangement of the plant and of the forms of the pulleys and other details employed.

An endless rope haulage plant has been laid down at the Kramsta mine, near Konradsthal, in Lower Silesia. It has a total length of 1·7 mile, more than half of which is above ground. The wire rope used passes through forked prongs, one on either end of the waggon being hauled.‡

The Priestman Oil Engine for Haulage.—Some notes on the working of a Priestman oil engine of eleven nominal horse-power, used for underground haulage, are given by Mr. W. H. Wain.§ The engine was put in to work an exploratory road, which is now 500 yards long, on a gradient of 1 in 5·64. The engine-house is built in the strata under the coal; it is $30\frac{1}{2}$ feet long, with an archway $9\frac{1}{2}$ feet wide. The engine is separated from the drum by a wall, and can be completely isolated by iron doors, if necessary. As the engine cannot be

* *Iron and Coal Trades Review*, vol. xlv. p. 108.

† *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 147-156, two plates.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 526, two illustrations.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 258-266, one plate.

reversed, gearing has to be used for reversing the drum, which is geared at one in five. The average time for a journey with two tubs of coal was 5 minutes 55 seconds; the total weight of the rope, tubs, coal, and water was 4110 lbs., which required 9·16 horse-power. The cost per hour for stores was 14·46d., and for labour 11·12d. Oil is taken down in 10-gallon tins, the consumption being 1·62 gallons per hour. The temperature in the engine-house averages 72° F., the quantity of air circulating being 822 cubic feet per minute. Exhaust gases are led direct to the return air-way by a 3-inch pipe, and an analysis of these gases shows a fairly complete combustion. For intermittent work these engines are probably not economical, although they are convenient. At present the starting causes some little trouble, but no attendant is required after the engine is started.

Electric Underground Haulage.—A description is given by Mr. J. C. B. Hendy,* of the electric underground haulage plant at the Pleasley colliery for hauling the coal from the dip. The installation is capable of giving 60 horse-power at the motor, and is at present hauling 400 to 500 tons in nine hours up an incline of 450 yards, but the distance will be extended to over a mile, with an average dip of 1 in 12. A branch endless rope a mile long and two 6-inch pumps 400 yards distant will also be worked. The dynamo is 725 yards from the motor, and the cable consists of nineteen copper wires of 15 Birmingham wire-gauge. The motor is shunt-wound, and the dynamo compound-wound. The main roads near the pit-bottom are lighted by twenty-four Swan incandescent lamps of 16 candle-power. The motor is placed in an engine-house 49 feet long by 17½ feet high by 14 feet wide, arched with brickwork 2 feet thick. To avoid danger from creep, the machinery is fixed on to five cast-iron girders 15 by 18 inches, built into the sides of the arching. The results of experiments with the plant are given. The percentages of losses and horse-power are—

	Horse-Power.	Per Cent.
Engine and large pulley . . .	7·4	20·9
Dynamo, cable, and lights . . .	14·7	41·5
Motor	2·3	6·5
Gearing and empty rope . . .	7·1	20·1
Load	3·9	11·0
	35·4	100·0

When the plant is doing the full work for which it is intended, a greater efficiency is expected.

* *Transactions of the Federated Institution of Mining Engineers*, vol. ii. pp. 537-541.

At the Cannock and Rugeley Company's colliery, Hednesford, a powerful plant for haulage purposes has been laid down, and is capable of bringing 140 to 150 tons of coal per hour up an incline of 1 in 18 and 700 yards long. A cotton belt 16 inches wide and gearing reduce the motor speed in the ratio of 32 to 1 at the drum. An endless-rope system is used. The generator is a 60-unit Elwell-Parker dynamo, giving 200 amperes at 300 volts when running at 400 revolutions. The motor is a duplicate of the dynamo, except that it is series-wound and runs at 350 revolutions. The current is conveyed by two insulated cables, and the return is through a bare cable in the shaft. An ammeter is provided to show the load.*

Electric Locomotives in Mines.—According to K. Eilers,† there are four electric mine locomotive plants in Germany, of which three were built by the firm of Siemens & Halske, and the other by the Allgemeine Elektrizität-Gesellschaft. Of these, the earliest was installed in 1882, and three of the plants are in use at coal-mines. At the Hohenzollern mine there are now two sixty horse-power generating dynamos, one being kept in reserve. The dynamo generates a current of 140 amperes at 300 volts, which is transmitted by two cables of 19 copper wires, insulated and protected, and 250 yards long, to the L-iron that serve as contact rails. The current is taken from these rails by sliding contacts on the locomotives forced against the under-side of the rails by springs. Resistances on the locomotive and a brake on a wheel connected with the armature allow the motor to be started gradually. At Zauckerode, the sliding contacts are replaced by trolleys running on wheels on the conductors. Further details and sketches of the plant employed are given by the author. The following table gives the results at the three mines:—

	Stassfurt.	Zauckerode.	Hohenzollern.
With electric traction—			
Average distance run, yards . . .	870	780	820
Maximum number of trucks per shift .	400	400	900
Weight of coal per truck, lbs. . . .	1760	1050	1210
Ton-miles per truck	0·38	0·23	0·25
Cost per truck, penny	1·03	0·39	0·36
Cost per ton-mile, pence	2·58	1·84	1·35
With hand labour—			
Cost per ton-mile, pence	6·8	4·2	3·6
With horses—			
Cost per ton-mile, pence	3·2	2·4	2·0

* *Iron and Coal Trades Review*, vol. xliii. p. 760.

† *Transactions of the American Institute of Mining Engineers* (advance proof).

In addition, an estimate is also appended of the cost of equipping and running an electric traction plant. That the work done is satisfactory is shown by the fact that more locomotives are being obtained, and at Zauckerode there are now two locomotives, at Hohenzollern four, and at Stassfurt also four running on three roads. No precautions had to be taken on account of gas, as the mines are free from firedamp.

Electricity in its Relation to Mining.—The application of electricity for the transmission of power in mines is discussed by Mr. E. Scott,* who states that above fifty mines are supplied with electricity in the United Kingdom. The distances to which power can be transmitted by this means are almost unlimited, as shown by the Frankfurt installation, where power was taken over a distance of more than a hundred miles. Among the applications of electricity are its uses for signalling, blasting, lighting, and driving any of the following machines:—Coal-cutters, pumps, hauling machines (whether on rope haulage or locomotive systems), extracting and winding machinery, drills, breakers, screening and jigging plant, fans, magnetic separators, and numerous others. The great function of electricity is that of power transmission, so that otherwise wasted energy in remote places may be used. Of the coal raised in the United Kingdom, some 6 per cent. is used at the colliery for power purposes, representing a consumption of six lbs. of coal per indicated horse-power. The cheapness of the fuel explains a good deal of the reluctance exhibited to adopting electrical installations; but they have the advantage of greater efficiency with reduced first cost and expenses, as compared with other systems, over distances above half a mile. The facility of handling the conductors, and the ease with which the machines may be moved, are two other advantages. Direct communication by spear-rods is heavy and cumbersome, wire-rope transmission is cheap to put down, but expensive to maintain, the leakage from pipes conveying steam, water, or air under pressure is pernicious to the roadways except in the latter case, whilst it always reduces the efficiency. On the other hand, leakage from an electric cable is much more readily obviated. For short distances rigid connection is undoubtedly the best, but under all other circumstances the author upholds electric transmission, and he instances a number of examples and tests to prove the point. The objections generally put

* Paper read before the Institution of Engineers and Shipbuilders at Glasgow, November 24, 1891.

forward are the supposed delicacy of the machinery, and the danger from fire and shock. The perfected machinery, however, that is now obtainable, is very unlikely to break down seriously, and the fact that all the moving parts revolve instead of reciprocate gives a simpler construction to the machine.

The advantages of electric transmission of power as compared with other methods are enumerated by Mr. D. S. Bigge.* The danger of sparking is discussed, and the various means by which it may be avoided are pointed out, the results of some tests being also given. The strength of the various parts of the machinery, and especially of the armature, are now sufficient to stand a good deal of rough usage. The danger from breakage of the cable is also fully dealt with, an account of Atkinson's safety cable † being given. The author then discusses the application to pumping machinery, and also gives an account of an installation at one of Lord Durham's collieries. In this the safety cables, enclosed switches, and commutators are used throughout the plant, which is used for pumping, haulage, and lighting. A considerable discussion ensued, in which, amongst other things, the safety cable received much attention.

The present limitations of electric power in mining is discussed at some length by Mr. I. Hale.‡ The generation and transmission of electricity are dealt with, also the losses in the line and working expenses are fully gone into with the aid of a series of curves. The author is of opinion that the cost of converters required for the three-phase and the alternating systems will counterbalance other economies. The various applications of electricity in mining-work are mentioned, especially the question of percussive rock-drilling by its aid.

A series of articles dealing generally with the varied applications of electricity to mining appear in the *Electrical World* § of New York.

A paper has also been read by Mr. D. S. Bigge,|| dealing with the application of electricity in mining-work.

Safety Electric Conductor for Mines.—Another safety electric conductor has been devised¶ for preventing the risks due to sparking

* *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 278-306.

† *Journal of the Iron and Steel Institute*, 1891, No. II. pp. 219-220.

‡ Paper read before the Colorado Scientific Society, February 1, 1892, one plate.

§ Vol. xviii. pp. 402, 414, 433, 448, 465.

|| Paper read before the Association of Belgian Mining Engineers, Liège, May 7, 1892.

¶ *Colliery Guardian*, vol. lxiii. p. 529, with illustrations. Compare the *Journal of the Iron and Steel Institute*, 1891, No. II. pp. 219-229.

when the conductor is broken. In this cable a part of the current is conveyed by a separate wire insulated from the main conducting wires. This wire, in one form, is straight and passes through the centre of a core round which the other wires are laid spirally, and are insulated by a further covering. The central wire being straight, is more likely to be broken in case of accident to the cable, and, as it is connected to a magnetic cut-out device at the generating station, its breakage will there interrupt the whole current. When concentric conductors are used, a separate wire is provided for each. As only a small part of the current passes through this separate wire, there is no spark if it is broken, so that a switch may be placed on it at the motor and used to cut off at the generator the whole current to the motor.

Steel Pit Props.—Illustrations are given to show the use of old or defective rails as pit props, as devised by Mr. W. W. Barnes. The rail ends are cut so as to fit together, and the rails may be bent so as to fit in any form of supports required. Either double-headed or flanged rails are used.*

New Explosives.—According to experiments by Cronquist,† the blows required to explode the following explosives, each about 0·4 gramme in weight, were approximately as follows:—

	Foot-Pounds.
Nitro-glycerine	2·1 to 5·7
Dynamite	3·5 „ 12·8
Gun-cotton, dry	5·7
Gun-cotton with 20 per cent. moisture	16·5
Sebastine	4·9
Romite, common	4·3
Romite, naval	13·7
Powder (fired only)	271·2
Bellite	448·4

According to Lindall, on the other hand, plastic dynamite is much more useful than romite or bellite, which are also very much lighter—as much even as 40 per cent. Comparative experiments between plastic dynamite and bellite which were made near Stockholm showed advantages in favour of the former, though Cronquist states that bellite shows not the least trace of flame on explosion. A mixture of 20 per cent. of dynamite with 80 per cent. of ammonia powder is also stated to be a very safe explosive as regards freedom from flame.

* *Iron and Coal Trades Review*, vol. xliii. pp. 752-754.

† *Ingeniörs-föreningens förhandlingar*, through the *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 542.

Nordenström observes that explosives, such as romite and bellite, which contain hydro-carbon derivatives, have as yet been comparatively little used in metal-mining. Fifty tons of romite was used at Gellivaara, but details are not available. These explosives are of little value for wet holes, and require much stronger caps than those usually employed. On the other hand, their transport is a matter of very little danger.

According to E. Pellissier,* comparative trials have been made in the district of Linares, Spain, of an explosive called nitramite and gelatine dynamite. In hand-boring the nitramite, though somewhat less powerful in its action, showed a saving in the expenditure, and this saving became considerable when compressed-air boring was employed. In this case, too, the work performed in the twenty-four hours was greater in the case of the nitramite than when dynamite was used. The tunnel being driven was advanced in the twenty-four hours 33·39 inches when dynamite was used and 34·97 inches when nitramite was employed, the respective costs being 2s. 11d. and 2s. 6d. per shift. The author observes that the action of the nitramite, though less violent than that of the dynamite, is more shattering. He recommends that in using nitramite the cartridges should be placed well home in the bore-hole and in intimate contact with each other, but not in any way compressed. The detonator must not on any account be allowed to detach itself during the charging of the hole from the central portion of the cartridge, as this has a different composition. If there is water in the bore-hole, extreme care must be taken that none of it penetrates into the cartridge or detonator. This requires peculiar care if the charge is to be fired after filling the bore-hole with water. The chief experiments in Spain with this explosive have been carried out at the Arrayanes mine under the direction of P. P. de Uhagón. The rock bored through in the experiments to which reference has been made was granite in the case of the hand-boring, and vein-stuff with some granite intrusions in the case of the machine-drilling.

A commission appointed by the Belgian Government has recently experimented with a new explosive. This is stated to be named "Fortis," and to be from 30 to 40 per cent. more powerful than any other explosive known. A comparatively small charge placed in a 13-foot bore-hole in the face of a quarry dislodged a mass 200 feet in

* *Revista Minera, Metalúrgica y de Ingeniería*, vol. xlii. pp. 306-308.

height, breaking it up into pieces mostly of from 50 to 60 lbs. in weight, and hurling some of these for a distance of 350 yards.*

O. Mühlhäuser † describes an explosive made from hemp and named nitro-hemp (nitro-jute). It is produced by treating one part of hemp with fifteen parts of nitro-sulphuric acid at a temperature of 15° C. After washing, this material is a brownish-yellow silky-looking wool, having the composition $C_{12}H_{15}O_5(ONO_2)_5$. It is insoluble in water, ether, benzene, or alcohol, but is soluble in acetic ether and nitrobenzene, or partially in ether-alcohol. In its explosive action it is almost identical with gun-cotton.

A new explosive named "Nico" has been tried at the Corporation quarries, Clifton Hill, Melbourne. A 4-foot hole in the toe of a solid piece of rock was charged with $1\frac{1}{2}$ lb. of cartridges and a little loose powder, the hole being too large for the cartridges. A second hole 6 feet deep was similarly charged with $2\frac{1}{2}$ lbs. of such powder, and a third with 2 lbs. Each of these shots gave successful results, as also did a number of others.‡

Methods for Testing Explosives.—To ascertain the duration of the explosive action, P. Vielle § has devised a registering crusher gauge. A steel point, attached to the steel plug which compresses the copper cylinder in a crusher gauge apparatus, is used to trace a curve on a revolving cylinder, which is driven at a speed of about 33 feet per second. The pressure of the gases generated by the explosion can be calculated from the composition of the explosive, or can be found from the deformation of the copper crusher gauge, while the pressure at any instant can be found from an inspection of the curve. By means of this apparatus it is found that the duration and also the manner of combustion varies very greatly with different explosives.

The Lauer Friction Igniter.—W. Stieber || discusses the varying action of the Lauer friction attachment in the explosion of those explosives which have nitro-glycerine as a base. Sometimes no explosion takes place, the explosive burning with flame instead, the flame issuing for some distance in front of the hole containing the charge.

* *Iron Age*, vol. xlviii. p. 523.

† *Chemiker Zeitung*, vol. xvi. p. 163.

‡ *Australian Mining Standard*, vol. vii. p. 201.

§ *Comptes Rendus de l'Association Française pour l'Avancement des Sciences*, 1890, p. 53.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. pp. 1-5.

It may thus readily give rise to explosions if burnt in collieries. In the author's opinion an ideal explosive would be one possessing the same temperature of detonation as it did of ignition.

Accidents from Blasting in Collieries.—Mr. J. Ashworth * deals with some recent accidents from blasting in coal-mines, and suggests some methods by which explosives might be tested. The first is that they should be fired by a bare fuse without a detonator, and that they should be tested in bore-holes of different sizes. Experiments should also be made when an air current of high velocity is impinging on the mouth of the bore-hole. High explosives should be used in bore-holes of a size proportioned to their strength as compared with black blasting powder. When a small-sized bore-hole is used, the tamping is stronger, and the explosive is distributed over a greater length, so that it can act over the same area as the powder. With regard to the air-current test, it has been noticed that the worst accidents have taken place when the shot faced ventilating currents of high velocity, perhaps because a detonating wave is set up. No explosive is safe in a fiery or dusty mine if its detonating vibration is like that of a mixture of fire-damp, coal-dust, and air. A wet length of road is invaluable in arresting coal-dust flame, but mere sprinkling the sides of the road with water is of no preventive value.

In discussing accidents from blasting in mines, Mr. J. Grundy † criticises a recent paper by Mr. J. Ashworth, which describes amongst others an accident at Ashton Moss colliery. The author shows that this may not have been due to a secondary explosion of gunpowder, but might be due to the sudden compression of the air generating heat. In testing explosives it is scarcely useful to explode them with a bare fuse, and without a detonator, and without any precautions, but they should be tested under the conditions in which they are to be used. It would be a suitable field of research to investigate the question of resonance of sound under varied conditions, so as to ascertain whether an explosive or vibratory wave is concerned.

Coal-Cutting Machines.—Mr. R. Sutcliffe ‡ finds that the best form of coal-cutting machine is one having a cylinder at each end and a cutting wheel in the centre, as a light machine of this type will keep

* *Transactions of the Manchester Geological Society*, vol. xxi. pp. 339-351.

† *Ibid.*, vol. xxi. pp. 439-444.

‡ *Ibid.*, vol. xxi. pp. 563-573.

the rails. The cutters should be fixed radially in the disc and hooked at their cutting edges to cut forward. A good machine should be strong and simple in construction, with few working parts. It should have sufficient base and weight to keep it on the rails without extra fittings; it should be able to cut either way, should be easily reversed, and should automatically remove the débris; and, lastly, it should not exceed 3 feet in width by 7 feet in length. The necessity for building the machines so as to cut either backwards or forwards is of vital importance, as much time is otherwise lost in bringing the machine back. For proper working, the working faces should not be made too long, but should be short enough, so that the fallen coal can be speedily removed, in order to keep the machine in regular work. The best mode of working would appear to depend on the subdivision of labour among holers, blowers, timberers and packers, and rippers. The holers would include a man to drive the machine, another to lay the way, and a boy to clear the débris. The whole of the men at the machine should be under the sole charge of a capable man.

The Ingersoll-Sergeant coal-cutting machine is described by Mr. W. Bell.* This machine is of the pick or rock-drill type. It weighs 500 lbs., and is 7 feet long by 15 inches high. The cylinder is 4 inches in diameter by 8 inches long, and air at 40 lbs. pressure is supplied through 1-inch piping. In one case in a seam 2 feet 2 inches high the machine undercut in some fireclay and brassy coal, making a hole 4 feet deep and 14 inches high in a heading $7\frac{1}{2}$ feet wide in one hour. Other times are also given. Two or three of these machines are at work in English collieries.

An illustration is given † of the Ingersoll-Sergeant channelling drill and bar, and of their coal-cutting machine, which is of the percussive or pick type, mounted on two wheels. The machine has two independent slide-valves, so that the length and force of the stroke can be adjusted.

An illustration is given ‡ of a coal-cutting machine of the chain-cutter type made by the Thomson Van Depoele Electric Mining Company. The carriage has two sets of axles, one with flanged wheels for ordinary travelling; the others, at right angles with the former, support the machine at the face. The latter wheels are flangeless and are kept on the rails by guide-wheels. The machine is changed from one set to

* *Journal of the British Mining Students*, vol. xiv. pp. 115-118, one plate.

† *Industries*, vol. xi. p. 509.

‡ *Engineering and Mining Journal*, vol. lii. p. 677.

the others by cams and screws. A fifteen horse-power motor is carried on the machine and is thoroughly shielded from injury. It drives the cutter chain through bevel and spur gearing, and also propels the machine along the face by means of a pair of pulleys which haul on to an anchored chain at any desired speed. The cutter chain runs on an arm which is adjustable in length to take up the wear of the chain, and is also adjustable radially. The chain and the cutters are forged, and the cutters can easily be replaced when worn.

The annual report of Mr. R. M. Haseltine,* Inspector of Mines in Ohio, devotes some attention to the question of coal-cutting by electricity. In this State there were fifteen Jeffrey machines at work at the close of 1890, and some tests of these machines were made and are given in tabular form, showing the size of the undercut, the time occupied, the maximum, minimum, and average electric horse-power used in cutting, and other details. The average horse-power required to undercut one square foot per minute varied from 4.2 to 12.4, with an average of somewhere about 9 to 10. The data given enable the generating power to be calculated for any required number of machines.

Some comments on these experiments are made by Mr. E. B. Richart,† who draws attention to the rough treatment that machinery of this class undergoes at the hands of the workmen. In some instances each fusible cut-out plug has been replaced by several so as to avoid interrupting the current, or the resistance starting coils have been dispensed with. The variations in power required according as the coal is hard or soft, or as the machine is in order or not, are very large.

Method of Working Thick Coal in South Staffordshire.—

A detailed description of the methods in use for working the thick seam in South Staffordshire is given by Mr. W. F. Clark and Mr. H. W. Hughes.‡ The invariable rule is to drive out to the boundary and to bring back the work, leaving the gob behind. Two main gate-roads are driven along the strike of the seam, and roads are branched out right and left. The roads are driven 9 feet wide, 6 feet high, and 33 to 45 yards apart, by holing 15 feet under, supporting the coal with props, and cutting vertical grooves, leaving webs of coal or "spurns." These spurns are then cut away and the props withdrawn, so that

* *Electrical World*, New York, vol. xviii. pp. 403-405.

† *Ibid.*, New York, vol. xviii. pp. 419-420.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 34-49.

the coal falls, leaving the road of the proper height. The methods of working may be conveniently divided into three, namely, square work, long-wall in two divisions, and long-wall, the whole thickness being removed at once. With the aid of plates showing the various stages of the work, a very clear and detailed description of the several systems is given, but without these figures not much idea could be gained from an abstract. In the first system the coal is worked out in a series of square chambers divided from each other by ribs, cross-drivings are made between the main roads to divide up the coal into pillars, which are then worked back, several modifications being used. In the system of long-wall in two divisions the top half is worked first, and, after the roof has settled, the lower part is taken out. For long-wall in one division the roof must be soft, and must come down without much weight.

The following table shows the relative economy of the three systems :—

	Square Work.	Long-Wall.	
		Two Divisions.	One Division.
Area worked, acres	10.5	18.925	21.694
Thickness of coal wrought, feet . .	24	23	17.5
Quantity per acre—			
Coal, tons	18,120	15,219	7,338
Slack, tons	11,713	16,933	12,879
Total, tons	29,833	32,152	20,217
Quantity per acre per foot thick of coal—			
Coal, tons	755	661	419
Slack, tons	488	737	736
Total, tons	1,243	1,398	1,155
Value per acre per foot thick of coal, £	475	478	357

The question of the workman's "stints," or the method of payment adopted, is also gone into.

Mining Thin Coal Seams in Missouri and Kansas.—According to Mr. A. Winslow, State Geologist of Missouri, and Mr. L. Gluck,* the general system of mining adopted in Missouri and Kansas is the long-wall method. Formerly it was generally thought that a tough and somewhat flexible roof was essential for the success of this method.

* *Appendix A. of the Report of the Geological Survey of Missouri for 1891.*

- In Missouri and the adjoining States, however, a system of long-wall working has developed by which the coal is taken out from under comparatively weak and unstable roofs.

When the roof is strong and flexible, four headings are driven in the coal at right angles to each other for a distance of from 20 to 50 feet, and from the ends of these, connecting cross-cuts are driven, from the exterior sides of which the coal is mined radially from the shaft. When the face has advanced some 800 feet, it is still pushed forward in the same direction as before, but the main headway is forked into two, forming an angle of 45° with the original direction of the main headway. When this has proceeded to such a distance that haulage along the face becomes excessive, the headings are again bifurcated, and the process is continued until the limit of the property is reached. When the roof is comparatively weak and brittle, a method of mining is pursued, which differs from that described in that less space is left between the advancing face and the packing which follows it. The details of long-wall mining are discussed by the authors, full descriptions being given of the methods of driving headways, of mining the coal, of supporting the roof, of haulage, of ventilation, and of drainage.

The fact that with these methods all the coal can be removed is their chief recommendation. The ease of ventilation and the simplicity of the plan of work are, however, further advantages. In order to obtain the best results, the work must be prosecuted regularly and uniformly, so that the face advances equally in all directions, and preserves approximately the shape of a circle.

Position of Miners at Work.—In a volume covering 144 pages, and furnished with 17 illustrations, Mr. S. Snell,* Ophthalmic Surgeon to the Sheffield General Infirmary, fully discusses the characteristics, symptoms, cause, and prevention of miner's nystagmus. Considerable controversy has arisen as to the causes to which nystagmus is due. It is claimed, on the one hand, that the cause of the affection is to be sought in the employment of safety lamps and the imperfect illumination of the mine. On the other hand is the theory, adduced by the author, that miner's nystagmus has for its prime cause the peculiar position which the collier is obliged to assume at his work. The affection, he conclusively proves, is occasioned by fatigue of certain muscles of the eye, induced as a consequence of the miner's work in

* *Miner's Nystagmus and its Relation to Position at Work, and the Manner of Illumination.* Bristol and London, 1892.

the pit necessitating an upward and more or less oblique gaze. It occurs irrespective of the mode of illumination.

Stopping Back-Water by Brick Dams.—An account is given by Mr. J. Niven* of the brick dams constructed at the Mirfield Moor pit for stopping back a heavy feeder of water. During the sinking of the pit a large amount of water came from the river through an open-jointed rock, and had to be tubbed out. Coal was met at a depth of 457 feet, or 110 feet below the Ordnance datum; and on driving towards the river, two up-throw faults raised the coal 70 feet. These were cut through by a stone drift rising 6 inches to the yard, and the workings continued to a distance of 300 yards from the pit-bottom. It was then found that a very large amount of water was coming through a stratum of 2 inches of soft dirt below the coal, and flowing down to the pit, where it had to be pumped from a depth of 200 yards. Brick dams were accordingly put both in the intake and return drifts. The dam in the intake was $10\frac{1}{2}$ feet wide by $7\frac{1}{2}$ feet high, and six courses of bricks in thickness with 1 inch of cement between each course. The dam in the return was somewhat smaller. The floor, roof, and sides were cut back 18 inches, and a 6-foot length of arching was placed on the outbye side of the intake dam, as the roof was weak. In ten days the pressure rose to 108 lbs. per square inch, but the dams have remained tight. The cost of the two dams was £70.

Hoisting Water from Mines.—Mr. J. H. Bowden† describes some tanks which were used for hoisting large quantities of water from one of the Susquehanna Coal Company's mines through a slope of small section, 3200 feet long, and varying in gradient from 4° to 20° . These tanks are self-filling and self-emptying, and they consist of a body on four wheels with doors at each end. The door at the rear opens inwardly, and the door at the front end is of smaller size and opens outwardly. The two doors are connected by an adjustable link, and as the front door is the smallest, both doors are kept closed when the tank is full of water. The tanks are mounted on self-oiling closed wheels, so as to exclude water from the bearings. Each tank is also provided with side-wheels vertically over the rear axle, arranged so as to run on a track arranged at the top of the slope, and to tip up the trucks so as

* *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 132-138, one plate.

† *Transactions of the American Institute of Mining Engineers*, Glen Summit meeting (advance proof).

to allow the front door to open and discharge the water into a channel between the rails. Two or more of these tanks are arranged tandem, and provision is made so that the couplings do not foul when the tanks are tilted, and the rails at the tilting-place are on a slight incline, so that the trucks run back automatically as soon as the hoisting rope is slackened.

Pumping Appliances.—Mr. H. Davey * deals with some of the general principles involved in methods of draining mines, and proposes the formation of a *depôt* where pumping plant could be obtained at short notice. Reference is made to the method recently proposed by the author † for draining shafts while they are being sunk by means of pumps in adjacent bore-holes, or by a sump driven in advance of the shaft. To replace steam for working underground pumps, hydraulic transmission of power is sometimes used with advantage. At the Grimthorpe Colliery, Sheffield, for instance, there are three hydraulically worked pumps in an inclined shaft. The first lifts 150 gallons per minute 300 feet high, the second 137 gallons 300 feet, and the third 30 gallons also 300 feet. Water under a pressure of 700 lbs. per square inch is conveyed to the pumps by pipes 4 inches, 3 inches, and 2½ inches in diameter. At other collieries the water column has also replaced the ordinary spear-rods. Several electrical installations are also mentioned.

Mr. J. Kenneth Guthrie gives an account ‡ of a successful method adopted to contend with the large accumulation of water met with during the sinking of the New or West Tyne pit, the shaft being 12 feet in diameter. Sections of the strata passed through are given, and it is stated that no water appeared until the Brockwell seam was reached, when some 400 gallons per minute was met with; this was removed by means of a compound engine of 20 horse-power, with 9-inch and 14-inch cylinders, working a 14-inch sett. This was found to be sufficient until the shaft came within six fathoms of the Crow seam, when the feeder increased to 700 gallons per minute, and a second 14-inch sett was put in, worked by the same engine. After winning the Crow seam, the work was found to be too much for the one engine, and another of locomotive type with two 16-inch cylinders and 5-foot stroke was erected; this worked the two setts already

* Paper read before the Cleveland Institution of Engineers, February 22, 1892, through the *Colliery Guardian*, vol. lxiii. p. 373.

† *Journal of the Iron and Steel Institute*, 1891, No. II. p. 201.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. ii. pp. 457-466, one plate.

referred to. The water continued to increase until 1550 gallons per minute were delivered, though breakages were very frequent, owing to the high speed of pumping, and it was soon found necessary to put in another sett of 19 inches diameter, as well as two iron water-cages, each capable of lifting 418 gallons; these latter run in wood guides as an ordinary cage, and are fitted with self-acting teeming gear.

The supply of water continuing to increase, the arrangements were found to be inadequate, and it was decided to erect a powerful pumping engine, sufficiently large to contend with any probable feeder that might hereafter be met with. A double horizontal compound condensing engine of the tandem type, having two cylinders and one air-pump in a direct line on one bed-plate 60 feet long, was adopted, the whole being massive in construction, with as many parts as possible adjustable, the engine working on to two large quadrants, and bolted to 16 feet of solid concrete. The pumping is continued with setts and buckets as before, but the number and capacity have been increased, there being at present in operation four bucket lifts, two 14-inch setts (only worked with the small engine when the large one is standing), one 24-inch sett, and one of 19 inches, room being left for another of 24 inches; the two large setts now in use raise together 277 gallons per stroke, or, at the present usual rate of seven strokes, 1939 gallons per minute. The engines are capable of running twelve strokes, and if all the setts and buckets for which there is accommodation were used at one time, 6100 gallons of water per minute could be raised. In the 24-inch sett the suction end is composed of a breeches-piece, having two legs 15 inches diameter, as otherwise the 24-inch sett would have stopped at the pit-eye. The length of suction of the 24-inch sett is given as 30 feet, and though this is a large amount, no difficulty has been found in pumping, the sett being quite solid.

In a sinking at the Rotherham Collieries, nine pulsometers were used to deal with the water, which attained a maximum flow of 130,000 to 140,000 gallons per hour at a depth of 150 feet. The shaft was 18 feet in diameter, of which the pulsometers occupied six feet. Steam at 80 lbs. pressure was obtained from boilers 352 feet from the mouth of the shaft.*

A description is given by P. Vanhassel† of a high-lift underground pumping engine at Leopold I. colliery, La Louvière, Belgium, where

* *The Colliery Guardian*, vol. lxiii. p. 1042, illustrations; *Engineering*, vol. liii. p. 601.

† *Revue Universelle des Mines*, vol. xv. pp. 1-13.

the water is raised through a height of 1881 feet at a single lift. This is believed to be the highest single lift in the world. The water is muddy and warm, as it has been used for condensation purposes. The engine is placed in a masonry-lined chamber, 49 feet long by 13 feet broad by about 14 feet high, near the bottom of the pit. A masonry-lined reservoir, holding 17,000 cubic feet, catches the water after it has passed over settling devices. The engine has a single horizontal cylinder, 2.46 feet in diameter by 2.52 feet stroke, provided with Meyer expansion gear adjustable by hand. The initial steam pressure ranges from $2\frac{1}{2}$ to $3\frac{3}{4}$ atmospheres effective, and cut off from $\frac{3}{8}$ to $\frac{1}{2}$ of the stroke. The pumps are two single-acting plungers of 4.32 inches in diameter, placed back to back and in line with the steam-cylinder and driven through a crosshead with two small heavy flywheels. All the water is passed through the condenser. In place of an air vessel, a plunger loaded by springs is used. The rising main is 5.9 inches in internal diameter, and has telescopic expansion joints every 65 yards. The steam-pipe is 7.67 inches internal diameter and has similar expansion joints. The useful effect of the engine and pump varies between 71 and 77 per cent., the discharge varying from 8600 to 13,000 gallons per hour.

F. Tonneau * describes the pumping engines used at Arsimont, in Belgium, to raise water varying in quantity from 400,000 to 1,000,000 gallons daily, partly from a depth of 220 yards, and partly from 280 yards, which latter will be deepened to 380 yards. Two compound horizontal engines placed at the upper level drive four plunger pumps, which force the water to the surface, and part of the power is taken by gearing to Rittinger telescopic pumps for the lower lift. The principal dimensions of the engines and pumps are given.

Electric Pumping Plants.—Mr. F. M. Wheeler † illustrates several mine pumps driven by electricity. The first of these, at the Hamilton Ore Company's mines, will lift 200 gallons per minute to a height of 1500 feet. It is driven by a Thomson Van Depoele motor, and the gearing is encased in an oil chamber and provided with arrangements to take up wear. The second was built for the Poor Man mine to raise 500 gallons per minute to a height of 1000 feet. Worm gearing running in an oil chamber is used between the pump and the motor, which is of the Edison vertical type.

* *Revue Universelle des Mines*, vol. xv. pp. 14-21.

† *Cassier's Magazine*, vol. i. pp. 75-79.

A note on the electric pumping plant at South Pontop colliery is given by Mr. J. R. Ritson.* The dynamo gives 20 amperes at 370 volts or $9\frac{1}{2}$ horse-power at 1000 revolutions, and the current is taken to a distance of 3700 yards by insulated lead and return cables. A series-wound motor, working at 1200 revolutions, uses 7·8 electrical horse-power and drives a centrifugal pump which lifts 200 gallons per minute through 300 yards of pipe with a vertical rise of 31 feet. The pump and motor are mounted on a carriage so as to be lowered as the water falls. The efficiency of the centrifugal pump is low, being only 33 per cent. From brake horse-power to water delivered, the efficiency is 14 per cent. The cost per day is 19s. 6d., as compared with 25s. for horse-pumping.

Some notes on a small electric pumping plant at the Shireland colliery are given by Mr. M. Deacon.† A 24-horse-power dynamo gives the current for lighting and pumping. The pump is of a three-throw horizontal type, driven by a 2-horse-power motor running at 900 revolutions and geared down from 25 to 1. The motor and pump are placed on a light frame so as to be portable. A safety commutator with inside brushes is used on the motor, and is cleaned daily. The quantity of water being pumped is about 40 gallons per minute against a gauge pressure of 26 lbs. per square inch. A series of tests showed that the indicated horse-power of the engine running light and loaded as above was 7·3 and 11·29 respectively; the dynamo gave 118 volts and 17 amperes; the motor, 98 volts and 17 amperes; the electrical horse-power given by the dynamo, 2·67, or 23·65 per cent. of that given by the engine. The total cost per annum is estimated at £103, 10s., as compared with £657 for hand-pumping. As the plant is designed for further extensions, the load is very light, and the efficiency accordingly low, being only $6\frac{1}{2}$ per cent. at the pump. There is a loss of 20 per cent. in transmission owing to the low voltage employed.

Some notes on an electric transmission plant at the East Howle colliery are given by Mr. H. Palmer.‡ A compound-wound Crompton dynamo, which gives 60 amperes at 550 volts at 770 revolutions, is driven by a pair of vertical high-pressure engines running at 160 revolutions per minute. The positive lead consists of 3000 yards of insulated 19/16 copper cable. The pumps are placed two miles from the shaft, and both are driven by series-wound motors with a current at

* *Journal of the British Society of Mining Students*, vol. xiv. pp. 82-84.

† *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 191-195.

‡ *Ibid.*, vol. iii. pp. 271-278.

500 volts. In No. 1, the motor running at 1100 revolutions, is geared down 15 to 1, and drives a pair of 7-inch double-acting pumps of 13-inch stroke. No. 2 motor runs at 1200 revolutions, is geared down 128 to 3, and drives a 9-inch double-acting pump of 36-inch stroke. The water is pumped through 800 yards of a 9-inch pipe, a size which is too small, but there is ample power from the waste gases of the coke-ovens. The results of a trial are as follows :—

	Indicated Horse-Power.	Percentage of Total Power.
Loss in engine	12·00	22·30
„ generator	3·62	6·72
„ cables	7·04	13·05
„ motors	3·36	6·25
Friction of pumps and pipes	18·94	35·28
Water lifted	8·80	16·40
	53·76	100·00

The total cost was £2157, including the cost of fifty-three incandescent lamps also run off the generator.

Removing Deposits from Pipes in Shafts.—Mr. R. T. Swallow * describes the method adopted for removing deposits from the inside of rising main pipes in a shaft at the Hepburn colliery. These mains are constructed of 118 cast iron pipes, in lengths of 9 feet, and varying in diameter from $9\frac{1}{4}$ to $10\frac{1}{4}$ inches at the surface. As one of the vertical pipes was split it was removed, and the waterway was found to be reduced from 9 to $6\frac{1}{2}$ inches in diameter. The broken pipe was replaced, and the pipes were cleaned by a process analogous to rope-boring of deep bore-holes. Two small pulley-sheaves were arranged to lead the rope from the winding drum so as to hang in the centre of the pipes, and a specially designed cutter was attached to the end of the rope. The cutter was loaded with 4 cwt. of chain, and consisted of a horizontal piece of bar iron, fitted with steel springs on each of the sides, and each carrying two knives. The cutter was reciprocated in the pipe, and a stream of water turned down it to wash away the debris. This operation was repeated twice throughout the whole length of the pipes, the second time the cutters being set to the full diameter required. Altogether $11\frac{1}{2}$ hours were required for the clean-

* *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 113-118, one plate.

ing process, and five men were required. The operation did not interfere with the use of the shaft, and five tons of deposit were removed at a trifling cost from the pipes, which had been in use for five years.

Ventilation of Fiery Mines.—The question of the ventilation of fiery mines is discussed by Rateau.* The origin of the gas in the mine is due to three causes—the liberation of occluded gas, especially from freshly broken coal during the working, blowers, and outbursts of gas from old workings. The old workings are generally in communication with the rest of the mine, and readily give out large volumes of gas as soon as the pressure falls. It is, therefore, very necessary not to alter the amount of ventilation rapidly. Mines containing firedamp in France are all included in one class, but the Austrian Commission has adopted a classification depending on the percentage of gas in the return air and on the output. This system, however, does not allow for sudden outbursts of gas. Mechanical ventilation is indispensable to keep the mine free from gas. Absorption by reagents is quite impracticable, but the use of separate pipes for taking gas from blowers or from isolated accumulations is advantageous in some instances, though not generally applicable. The only practical means is to introduce sufficient volumes of air to sweep out the gas, and in such a manner as to oblige it to mix thoroughly. On account of dust, the return air should never contain more than 1 per cent. of gas, and it is preferable to reduce it to less than 0.5. In the mine, the air is broken up by splits, but no current should be at a smaller pressure than 1 inch water gauge, or its persistence is doubtful. In any case, the amount of air passing through the mine should be as great as possible, with a considerable difference of pressure. It is also very necessary that the gas should be thoroughly mixed with the air, and for this purpose small portable ventilators are very useful. The main ventilator either exhausts from, or forces air through the pit. Generally the exhausting fan is used, but if the other method can be adopted, it is in the author's opinion preferable, as its installation is cheaper, the inspection more easy, and it gets less dirty and requires less cleaning. Reversible ventilators do not appear to have done much good. The installation of the main fan at the bottom of the pit is condemned as being costly and difficult to get at, especially in case of accident. A fan was put down on this plan at the Shamrock mine in Westphalia, but was found to be very inconvenient. The fan was $11\frac{1}{2}$ feet in diameter,

* *Société de l'Industrie Minérale, Comptes Rendus Mensuels*, 1892, pp. 40-53, one plate.

and placed with its engine in a chamber $50 \times 20 \times 18$ feet high. Secondary ventilators in the mine are preferably worked by compressed-air motors and are generally used for blowing, but exhausting fans are sometimes useful. If they are used, the pipes may be placed near the roof, and pierced at intervals to draw the gas from cavities or from between the head timbers. These fans are also preferable for removing smoke after blasting. What are called by the author ventilators of the third degree may also be used. One of these, devised by Favet, is shown, and consists of a small fan driven by the current of air in the gallery and provided with a flexible hose. The author then proceeds to compare furnace and steam ventilation with ventilation by fans, and shows that the latter is more efficient at depths not greater than 300 yards.

In a series of articles on accidents in mines, their cause, warnings, and prevention, Mr. W. H. Thomas* discusses the mode of existence of firedamp in the coal and the various systems used for ventilation. He is of the opinion that ventilation should always be performed by forcing air into the mine instead of by exhausting the air. For this purpose the fans now in use would generally be sufficient, and he gives a sketch of an arrangement for carrying his ideas into practice. The main idea of using compressive ventilation instead of exhaust, is to control or regulate the emission of gas.

The Ventilation of Lignite Mines.—C. Balling† discusses in detail the question of colliery ventilation, referring more especially to lignite mines. He refers in the first place to the quantity of air required at different temperatures for breathing, both by men and horses, then to that used for lamp combustion, to the absorption of oxygen by the coal, and by various animal and vegetable matters existing in the colliery. Next the question of the hydrocarbons, sulphurous anhydride, ammonia, carbonic oxide and carbonic anhydride of the colliery atmosphere is considered. The influence of the temperature of the workings on the power of the workmen to perform labour is stated to be as follows:—

Rise of Temperature.	Diminution of Work done.
From 20° C. to 25° C.	5 to 10 per cent.
" 25° C. to 30° C.	10 to 15 "
" 30° C. to 35° C.	15 to 30 "
" 35° C. to 40° C.	30 to 50 "

* *Colliery Guardian*, vol. lxiii. pp. 251, 279, 327, 416.

† *Ueber das zur Ventilation von Grubenbauen erforderliche Luftquantum, &c.*, by C. Balling, Teplitz, 1891; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. pp. 101-104.

At a depth of about $15\frac{1}{2}$ fathoms there is an equal temperature all the year round, and for every $15\frac{1}{2}$ fathoms increased depth there is a rise of 1° C. Even a very rapid current of air will not diminish this temperature to any marked degree. The temperature of the workings is also dependent to a considerable extent on the body heat of the men and horses in the mine, and on the combustion of the oil used in the lamps for lighting purposes. By doubling the quantity of air used, in an example given the temperature was only reduced from 24.7° to 23.7° , and then the velocity of the air current had become so great that a further reduction of temperature by this means had become impossible.

Centrifugal Ventilators.—Most of the machines in use in America for ventilating are, according to Mr. R. Van A. Norris,* of the class of centrifugal ventilators, being either open periphery fans or closed with a chimney and spiral casing of a more or less modified Guibal type. The theory of such machines, according to the well-known investigation of Mr. Daniel Murgue, leads to two generalisations, which are that the volume produced by any ventilator varies directly as the speed of rotation, and that the depression varies as the square of the speed. An attempt has been made by the author to test experimentally the effect on the efficiency of fans in actual use of modifications in the design of their various parts and in the condition of the mines. With this view a large number of tests of no less than twenty-five different fans have been made or collected. In a tabular form are given the following details:—Type of fan, diameter and width of fan, number and diameter of inlets, size of shutter, revolutions per minute of engine and fan, peripheral speed of fan, cubic feet of air per minute, per revolution, and per hundred feet peripheral motion, cubic contents of fan-blades, water-gauge, horse-power in air, indicated horse-power of engine, efficiency of engine and fan, and equivalent orifice of mine. Besides this tabulated statement, other details are given of the fan, of the mine, and of the details of working. In many instances an illustration of the fan is also appended to show the shape and disposition of the blades and casing.

An examination of the detailed results shows a mass of contradictions from which it is exceedingly difficult to draw any satisfactory conclusions, but the following appear to be more or less warranted by

* *Transactions of the American Institute of Mining Engineers*, Glen Summit meeting (advance proof).

some of the figures :—Mines with varying equivalent orifices give air per 100 feet periphery motion of fan within limits as follows, the quantity depending on the resistance of the mine :—

Equivalent Orifice.	Cubic Feet of Air per 100 Feet Periphery Speed.	Average.
Under 20 square feet . .	1100-1700	1300
20-30 " . .	1300-1800	1600
30-40 " . .	1500-2500	2100
40-50 " . .	2300-3500	2700
50-60 " . .	2700-4800	3500
60-70 " . .	3300-5100	4000
70-80 " . .	4000-4700	4400
80-90 " . .	5000-5600	4800
90-100 " . .	...	...
Over 100-114 " . .	5200-6200	5700

It would seem, on the whole, that large air-ways tend to assist somewhat in attaining large efficiency. The influence of diameter on the performance seems to be practically *nil*, the only advantage being the greater width and the lower speed required of the engines. The influence of the width appears to be small as regards efficiency, but the wider fans exhaust more air. Within reasonable limits, the shape of the blades appears to have no influence. Certain fans with blade tips curved backwards, others with straight blades, and others again with blades curved forwards at the tips, all give high efficiencies over 70 per cent. One advantage of curving back the tips is that there is less vibration on passing the point of cut-off. The blades should not project within the circle of the inlet. The influence of the shape of the spiral casing appears to be considerable. The shapes in use fall into two classes, the first presenting a large spiral beginning at or near the point of cut-off, and the second a circular casing reaching round three-quarters of the fan with a short spiral reaching to the *evasée* chimney. Fans with the first form of casing give large efficiencies in almost every case, while the efficiency is decidedly low with the second form, and moderate with intermediate forms. The best form appears to be a spiral, which allows the increasing volume to be swept forward regularly, and to escape with a velocity slightly lower than the peripheral speed of the fan into the *evasée* outlet. The shutter certainly appears to be an advantage, as the exit is regulated and eddies and re-entry of air avoided. It is noticeable that high efficiencies were given by fans running at rather high peripheral velocities, the best speed appearing to be between 5000 and 6000 feet per minute. Nearly

all the fans tested increased in efficiency up to this speed, and decreased in efficiency rapidly above that point.

A satisfactory way of testing fans would be to run them so as only to draw air through a passage say 50 feet long by 10 feet square, the size of the inlet being reduced in successive experiments until the inlet was entirely closed. This, however, is not always possible.

Some additional facts were elicited in the discussion on this paper; amongst others, the advantage of using the Walker shutter is clearly shown. Mr. A. H. Storrs* shows that some of the open-running fans empty themselves from one and a half to nearly four times per revolution. Turning the blades round was said in one instance to have given better results, according to Mr. R. Allison. Some comparisons of several fans by Murgue's theory are also given by Mr. Storrs, who thinks that this theory obviates the necessity of testing different fans in the same mine.

A short account of a theory of turbine machines generally, which include ventilating fans, is given by Rateau.† The theory supposes that the machine is perfect in its action, and an analogy is drawn with the theory of dynamo-electric generators.‡

The results of some experiments made in June 1891 with Waddle fans at the Pleasley and Teversal collieries are given by Mr. J. C. B. Hendy§ in a tabular form, showing the water-gauge, barometer, temperature, speed of fan, volume of air, horse-power, and fuel used, with the cost and the percentage of useful effect. Two 40-foot fans with 14-foot inlets gave an efficiency varying from 33 to 37 per cent. on the air in the drift. A smaller fan, 30 feet in diameter, gave 47·8 to 53·4 per cent. efficiency. Tests with a Capell double-inlet fan, 12½ by 11½ feet wide, and having inlets 7½ feet in diameter, are also tabulated. This fan at the Silver Hill colliery gave an efficiency of 44·2 to 47·0 per cent.

A description of the Chandler patent fan is given by Mr. R. S. Williamson.|| This fan has been successfully used for the last ten years for forced draught in ships, but has only been adopted for mine ventilation in the last two years. One of these fans, 6 feet 6 inches in

* *Transactions of the American Institute of Mining Engineers*, Glen Summit meeting (advance proof).

† *Société de l'Industrie Minérale, Comptes Rendus*, 1891, pp. 252-254.

‡ *Comptes Rendus de l'Académie des Sciences*, vol. cxiii. pp. 463-465, 637-639.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. ii. pp. 534, 542, 548.

|| *Ibid.*, vol. iii. pp. 171-174, one plate.

diameter, and 2 feet 5 inches wide, and running at 270 revolutions per minute, has been running at the Wimblebury pits of the Cannock and Rugeley collieries since March 1890 without requiring repair. The fan consists of a central disc of steel boiler plate mounted between faced bosses on a shaft running in outside bearings. On each side of the disc are mounted twelve blades, which are shaped like a flattened S. The fan is open running, and has an air inlet on each side. Details are given of experiments with two of these fans, which show efficiencies of 56·95 and 70·13 per cent. respectively.

The application of these fans for the production of forced draught on board steamers is further described by Mr. S. H. Terry.* For this purpose the fan is coupled direct to the Chandler single-acting engine.

Mr. W. Hopton† describes a form of fan recently devised by him. It is of the centrifugal type, with double entry, and has eight curved arms. This fan is also described by Mr. J. Tonge.‡

An account is given by Mr. W. Cochrane§ of an investigation into the working of two Guibal fans made in 1868 at the Duffryn collieries in South Wales. The fans were 30 feet in diameter, and each could pass 80,000 cubic feet of air at 1·60 inch of water-gauge when running at 58 revolutions. If both were run together at this speed, there was no important alteration in the amount of air, but a slight variation in the water-gauge. Both fans were working on the same upcast shaft, and the air-drifts and passages were arranged so that the fans could work tandem, or so that either could work separately. By this tandem or duplex arrangement, the leading fan imparted a second and equal quantity of work to the air which had already been passed through the fan nearest the upcast. Experiments gave the results that on the tandem arrangement the air passed was 108,479 cubic feet at 60 revolutions, with water-gauges at 2·10 and 1·10 inches at the inlets to the two fans. There was thus 35 per cent. increase. The indicated horse-power was 179·65 as against 70·20 for each fan working alone, showing very nearly the theoretical proportions of the cubes of the volumes of the air. Details are also given of experiments with one fan standing and the other running under various conditions.

F. Straka|| describes an underground plant which has been put in

* *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 175-178.

† Paper read before the National Association of Colliery Managers, April 9, 1892; *Colliery Manager*, vol. viii. p. 63.

‡ *Transactions of the Manchester Geological Society*, vol. xxi. pp. 582-587.

§ *Transactions of the Federated Institution of Mining Engineers*, vol. ii. pp. 483-488.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. pp. 481-485, and 498-501, with two sheets of illustrations.

at the No. 3 shaft of the Danube Navigation Company's colliery near Fünfkirchen, in Hungary. It consists of a Guibal fan, a Rittinger fan at the surface having been found, during the sinking of this shaft, to give too poor a ventilation, owing to the greater quantity of gas met with at increasing depths.

Water-Gauges for Ventilators.—The Lee alarm water-gauge is designed to automatically give an alarm if the pressure falls unduly. One leg of the gauge is in connection with the ventilating current as usual, and the other leg contains a float. The top of this float contains a small quantity of mercury, which, when the float rises to a certain height, will complete the circuit between two platinum wires carried by a plug in the end of the tube, and thereby sound an alarm. The contact device may also be placed in the other limb to indicate if the pressure rises owing to a fall of roof or other stoppage of the airways.*

An apparatus is being introduced in many of the mines in the American anthracite regions for registering the ventilating pressure and indicating when the volume of air furnished by the ventilating fan falls below the required amount. In order to accomplish this result, a small tube running from the return airway at the ventilating machine, or in the mine, is connected with a flexible diaphragm. Any change in the density of the air in the mine at once causes a movement of this diaphragm, which actuates a registering pen and makes a continuous record upon a revolving circular chart. This chart is rotated by a clock, and is divided into spaces for seven days and seven nights. By means of this automatic arrangement, a continuous record of the condition of the ventilation is kept for one week, at the end of which time a new chart is supplied.†

All the factors which it is necessary to observe in carrying out the ventilation of mines may, according to Rateau,‡ be measured by an instrument which consists mainly of a floating bell or cylinder. Any difference in pressure between the air inside and outside this bell will cause it to rise or fall, and the motion can be magnified. This amplified motion can be used to automatically register any variations in the speed or volume of the air current, and it is shown mathematically how the work performed may be determined by it.

* *Transactions of the Federated Institution of Mining Engineers*, vol. iii. p. 128, with illustration.

† *Iron*, vol. xxxviii. p. 444.

‡ *Société de l'Industrie Minérale, Comptes Rendus*, 1892, pp. 54-59, one plate. 1892.—i.

Fan-Testing Gauges.—Some notes on fan gauges in connection with fan-testing and the adaptation of fans to mines, and also a comparison of the fan and furnace at Silver Hill colliery, are given by the Rev. G. M. Capell.* It is considered that the most satisfactory position for taking the gauge is 6 to 10 feet away from the inlet in the larger part of the fan-drift. The German practice of deducting the work of the air due to its velocity is not considered fair. After many observations, the author advises that the end of the gauge should be plugged with cotton-wool and wrapped with soft flannel; but definite rules for the position and use of water-gauges ought to be drawn up and adhered to in all fan-tests. Where fans have taken the place of furnaces, some curious results have been observed, and this may arise from the fact that the gauge in furnace ventilation does not account for the shaft friction in the up-cast and down-cast shafts. Direct calculations probably give too high results for these factors. The author then proceeds to give the results of some tests with furnace and with fan ventilation to illustrate the difference in the gauges obtained by the two methods.

Safety Lamps.—More than 100,000 Wolff benzine lamps are now in use. Benzine is the luminant employed. In consequence of the clearness of this light, a much finer wire-mesh can be employed than is possible for an oil-burning lamp. Re-lighting may be effected without opening the lamp, but great care has to be taken to keep this attachment clean. The lamp burns for fourteen or fifteen hours without refilling. This lamp would have come into still greater use were it not for the difficulties connected with the storage of the benzine.†

In a paper read before the Mining and Metallurgical Association of Moravian-Ostrau,‡ K. Cizek discusses the value of the Wolff benzine safety lamp as ascertained by actual colliery use. After referring to the results of the tests of the Austrian Fire-damp Commission, and to the best dimensions for the double-gauze lamp, the author proceeds to discuss two observations which have recently been made when using this form of lamp. The usual instructions found in articles on safety lamps lay great stress on other points, but very little on the lighting attachments, and yet this is all-important, as the author's experience

* *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 196-200.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 571.

‡ October 7, 1891, through the *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. pp. 27-30.

has shown. In the colliery in which this experience was gained, 800 lamps are in daily use. For each shift eight or nine men place the 400 lamps in order, and special attention is paid to the locking and screwing of the lamps, four men being told off for this purpose for each hundred lamps. One hour before each shift, six foremen have again to test the lamps thus prepared, and, by blowing, to see that the locking is complete. It was thought that in this way the maximum degree of safety had been attained, and yet one of the lamps was one day brought out of the pit with the announcement that the flame had come through the gauze. The lamp had been placed on the floor of a level in a strong current of air. Nothing wrong could be found when the lamp was examined, and even in the well-known Wolff benzine apparatus no explosion could be effected; it was not possible to make the flame pierce the wire cylinder. When, however, the lamp was hung up in benzine vapour an explosion was effected. It was found that the lighting arrangements were the cause, the flame in the lamp coming out through this. Another lamp, almost immediately afterwards, was observed to have the same defect. An investigation of all the lamps in use showed that this defect was a common one, six lamps failing out of some 2500 tested. A temporary attempt to do away with this source of danger lay in soldering up the orifice with tin. The author describes the arrangements which were finally adopted for this purpose.

The Wolff benzine lamp is further discussed by E. Mládek.* The author particularly refers to the rotating lighting attachment of this lamp, which he shows has proved unsatisfactory and dangerous. He describes a modified arrangement.

A short account of the Thorneburry safety lamp is given by Mr. E. B. Wain,† with an account of the results of several experiments on it under varying conditions of speed and direction of the air current.

Shot-Firing Lamp.—The Roberts shot-firing appliance can be attached to any form of safety lamp. A brass tube $\frac{5}{16}$ inch in diameter is inserted through the oil cistern, and its top is terminated in a brass box covered with gauze. A hole is made in the tube opposite the flame, and is normally closed by a sleeve pushed up by a spring. The lower end of the tube is also closed by a plate pushed over it by a spring. A blowpipe also passes through the oil cistern

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. pp. 81-83.

† *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 226-228.

and is closed like the lower end of the tube. To fire the fuze it is pushed through the tube, the sleeve is drawn down by the pricker, and the flame is directed on to it by the blowpipe. When it is certain that sparks will not be thrown from the end of the fuze, it may be withdrawn.*

Lock for Safety Lamps.—M. Rateau † describes the special key used to open the lock on the safety lamp of Postolka and Eliasch, which is used at the Karwin collieries. This lock consists of a screwed bolt and a sleeve screwed both externally and internally. It can only be opened by turning the parts at an equal rate in opposite directions, and this is done by means of the key, which consists of a sleeve enclosing a spindle, these two parts being geared together by bevel gearing consisting of three wheels. A key for closing the rivets is also shown.

Electric Safety Lamps.—According to Shulz, ‡ the first accumulator was shown ten years ago, at the first International Electrical Exhibition at Paris, and the first portable safety lamp with accumulator was devised by Swan. The great weight of this lamp prevented its extended use, and it is only recently that electric lamps fulfilling the requirements of the mining engineer have been constructed. The author gives the following comparison of the electric safety lamps § shown at the Frankfurt Electrical Exhibition :—

Name.	Weight. lbs.	No. of Cells.	Current.		Duration of Charging. Hours.	Duration of Light. Hours.	Candle- Power.
			Amperes.	Volts.			
Pollak .	3.79	2	0.8-1	5.5-6	8	10-12	0.7-0.8
Bristöl .	5.22	2	1	5.3	7-8	8-10	1
Swan .	5.73	4	0.8 ?	9 ?	8 ?	10 ?	1½-1
Stella .	3.53	2	1	5	5-6	12	0.7-0.8
Bréguet .	6.39	4	1	10	12	18-20	1

Several forms of miners' electric lamps are described by E. Masson, || special attention being given to the Stella lamp and to the various experi-

* *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 129-130, with illustration.

† *Société de l'Industrie Minérale, Comptes Rendus*, 1871, pp. 246-247, one plate.

‡ *Glückauf*, 1891, No. 90.

§ Descriptions of these lamps are given in the *Journal of the Iron and Steel Institute*, 1891, No. 11.

|| *Association des Ingénieurs Sortis de l'École de Liège ; L'Annuaire*, 1891.

mental and other uses of these lamps. At Risca colliery the author found that in 1890 a hundred Swan lamps were in daily use. The rules for the use of these lamps are given in full. According to Mr. Brookes, these lamps, which weighed 7 lbs., gave excellent results for six months, and were preferred by the miners. After that time the lead plates warped and short-circuited the current, and the acid corroded the connections considerably. The trial with these lamps was given up after about eight or nine months. Other forms of lamps were also tried at the same place, but also had to be given up owing to corrosion of the connections or for other reasons. After mentioning several other forms of lamps, such as the Pitkin, the Bristol, and the Peto lamp, the author refers to the trials at the Rochebelle colliery* of the Stella, Pollak, Bréguet, and Edison lamps. The Stella lamp was selected as the best at these trials, and this choice is confirmed by the practical experience of the author. At Anzin colliery 400 of these lamps were being made in June last, and a list is given of several companies who have tested this lamp. The cost of installing and maintaining this form of lamp is stated.

Testing for Fire-Damp and Testing Safety Lamps.—Professor F. Clowes† describes a lamp which he has devised for testing for the presence of fire-damp or of inflammable vapour in the air. The lamp burns benzolene or oil, but in addition it is provided with a small store of compressed hydrogen, which can be burnt at the mouth of a small copper tube placed near the wick. The advantages of using the hydrogen flame for testing can thus be secured without the necessity for carrying a second lamp for illuminating purposes, as is necessary when the Pieler alcohol lamp is used.

The author's apparatus for testing safety lamps has also been somewhat modified and improved. In the latest form, the apparatus has a water-sealed door both at the top and at the bottom, so that the air in the chamber can be rapidly changed. Part of the mixing flap is also cut away, so that the air can be mixed after the lamp is in the chamber.

Large amounts of fire-damp can readily be found with any form of lamp, but for quantities below 2 per cent. a specially devised lamp and careful testing is necessary. The importance of detecting these

* *Journal of the Iron and Steel Institute*, 1891, No. II. pp. 225-226.

† *Proceedings of the Royal Society*, vol. li. pp. 90-95; *Industries*, vol. xii. p. 356; *Colliery Guardian*, vol. lxiii. pp. 653-654.

small amounts, according to Professor F. Clowes,* is due to the fact that they become dangerous if dust is also present. Besides this, the power of finding these small quantities of gas affords a ready means of testing the efficiency of the ventilation of the mine. The only trustworthy method of gas-testing depends on the fact that even the smallest percentages of gas will burn if kept in contact with a sufficiently hot surface. Up to the present time, the most satisfactory apparatus is that of Liveing, though Maurice's apparatus is also sound in principle. The objections to Liveing's device are that it is costly, that it necessitates carrying a special apparatus, and that the spirals become useless through over-heating. The Pieler lamp is mentioned as being extremely sensitive, and a still more delicate test is found in the use of the hydrogen flame. Reference is made to the author's apparatus for testing safety lamps, and to the Hepplewhite-Gray lamp modified by Ashworth.

Fire-Damp Indicators.—The fire-damp indicator of Mr. T. J. Murday† depends on the different heating and the consequent expansion of two platinum wires, both of which are heated by the same electric current, but one is exposed to the air of the mine and the other is enclosed. The two wires are connected by a system of levers to a pointer, so that any difference of expansion is shown, and the percentage of gas present can thus be determined. Illustrations of the device are given.

The Rate of Explosions in Gases.—A résumé of the state of knowledge on the rate of explosions in gases is given by Professor H. B. Dixon,‡ with an account of further experiments made by him, and the conclusions drawn therefrom. Bunsen measured the velocity in 1867, and his method of experimenting gave very low rates, but in 1881 papers by Berthelot, Mallard, and Le Chatelier announced that the velocity was really enormous. Berthelot's experiments were repeated and extended by the author, and his results on many points confirmed. The rate in various gaseous mixtures and the effect of moisture and inert gases were determined. For a mixture of equal volumes of marsh gas and oxygen, Berthelot gives a speed of 2287 metres per second, and the author gives 2322.

* Lecture at Nottingham, through the *Colliery Guardian*, vol. lxiii. p. 345.

† *Transactions of the Federated Institution of Mining Engineers*, vol. ii. p. 469, one plate.

‡ *Proceedings of the Royal Institution of Great Britain*, vol. xiii. pp. 443-450.

Explosions of Coal-Dust in Mines.—The first report of the Royal Commission on Explosions from Coal-Dust in Mines has recently been issued. As the inquiry is not yet complete, no opinions or recommendations are offered. Twenty-three witnesses have been examined, and the general opinion appears to be that coal-dust has been a powerful factor in many mine explosions.

Mr. H. Hall * returns to the question of coal-dust and its effect on colliery explosions. Mention is made of the various means employed for laying and diminishing the dust. No serious attempts have been made to deal systematically with the dust at each working face, but the author has seen a long-wall face dealt with by watering-tanks and watering-cans. Such a method, however, entails great expense. The most recent experiments with explosives in the presence of a dusty atmosphere are given. In many mines 10 per cent. of the shots are fired in the presence of gas, and as dust is also present, no explosive is absolutely safe. Damping the air, however, is efficacious to a certain extent in reducing the danger. There was an extensive discussion on the various points raised, and several suggestions were made. The author in reply stated that he believed coal-dust *per se* would explode. In his experiments the dusty air exploded with considerable violence. No doubt much of the danger depended on the mechanical condition of the dust, and an explosion might occur in the workings quite as readily as in the main roads.

Professor T. E. Thorpe † describes an apparatus by which the phenomena of a coal-dust explosion, resulting either from a local explosion of fire-damp or by the direct action of a blown-out shot, may be illustrated. Instead of coal-dust, lycopodium may be used, on account of the greater ease and certainty of the experiment, and also because its use allows of the observance of certain phenomena, such as the mode in which the dust which escapes complete combustion is thrown on projecting objects, and also the fact that the explosion gathers strength as it progresses, which is made evident by the gradually increasing area of clear space before such objects as the dust is swept away by the force of the explosive flame.

By observations made with a manometer in this apparatus, it is found that there is no evidence of a diminution of pressure along the sides of the space through which the flame rushes, and the author

* *Transactions of the Federated Institution of Mining Engineers*, vol. ii. pp. 415-431. Compare *Journal of the Iron and Steel Institute*, 1891, No. 1. pp. 335-338.

† *Journal of the Chemical Society*, March 17, 1892.

is of opinion that there is no experimental proof of the validity of the "suction theory" held by certain colliery managers, which assumes that in consequence of this alleged diminution of pressure occluded fire-damp is drawn out of the coal and contributes to the violence of the explosion. This subject was also dealt with by the author in a lecture at South Kensington Museum.*

The coal-dust at the Zauckerode colliery belongs to that class which, according to Atkinson, is especially dangerous. The seam worked is three to five yards in thickness, and three explosions have recently occurred, so that the question of the coal-dust had to be considered. According to M. Georgi,† two methods of obviating any danger are in use; safety explosives are employed and the dust is laid by the use of water-spray. Flameless dynamite, roburite, securite, and carbonite were the explosives chosen. It was found that all flameless dynamites deteriorate with keeping, and all evolved noxious gases. Roburite was uncertain in its action and liable to decomposition, so that these two explosives were abandoned. The results with securite and carbonite were more favourable. Carbonite is completely exploded by a detonator containing 0·8 gramme, and acts best in coal and soft rock, securite being best adapted for hard rock, and requiring a detonator with 1·5 gramme. The cost of driving with these explosives is always greater than with powder.

The installation of pipes was begun in May 1890 for leading water to the driest part of the mine from a water-level about 97 yards above. Cast iron mains 2½ inches in diameter are used, and all other pipes are of galvanised wrought iron. Sixty working-places are provided with spraying devices, of which the author gives illustrations.

Explosions in Collieries.—In the final report‡ of the Austrian Commission on this subject, various analyses are given of the gas collected from "blowers" and of that found in bore-holes. The results of the analyses vary greatly, the following being examples of the variations observed:—

	CH ₄ .	N.	CO.	O.
I. . . .	79·16	17·04	3·19	0·61
II. . . .	95·11	0·48	4·07	0·34

Other analyses show that the percentage of carbonic oxide present in the gas from bituminous coal may reach as much as 56 per cent.,

* Delivered March 19, 1892; *Industries*, vol. xii. p. 307.

† *Jahrbuch für das Berg- und Hüttenwesen in Königreiche Sachsen*, 1891, pp. 1-15.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxviii. pp. 464, 465.

whilst the percentage of this gas in that obtained from lignite varies from 36.78 to 89.65. The explosive character of mine-gas is due to the marsh gas which it contains, and of all mixtures of this gas with air, the most explosive is that which consists of 1 part by volume of marsh gas with 9.57 volumes of air, or in other words, which contains 9.46 per cent. of marsh gas. Marsh gas burns to carbonic oxide and water even when an excess of air is present, and the condensation after an explosion of the moisture so formed leads to the formation of a partial vacuum. With regard to the question of gas diffusion, it was found that in quiet air, the gas entering from the side, diffusion was complete in about three hours. The tension of the gas in coal varies considerably. In a bore-hole in the Olga seam at Privos, J. Spoth found the gas to have a tension of 9.2 atmospheres at a depth of 21 feet, while at a similar depth in the Carl seam at Dombrau the tension was 5.3 atmospheres.

The fuel deposits of the Alpine districts of Austria are mostly of Tertiary age, and they occur only to a much smaller extent in the Upper Trias and Neogene strata. Lignite is consequently the most important object of the mining industry of these districts, and the occurrence of gas in this portion of the Empire forms the subject of a portion of the report.

In Moravia the composition of mine-gas is different from that observed elsewhere, the quantity of marsh gas found in the gas of the Rossitz district especially being so small that in the return air from the collieries analysis fails to show its presence. Were it not for the presence of easily combustible coal-dust the collieries of Moravia would, therefore, be of an extremely safe kind.

Among the most dangerously explosive coalfields of Europe that of Ostrau-Karwin must be grouped. In this coalfield the percentage of marsh gas found in the gas is very high, varying throughout the mines examined from 79 to 99 per cent.

The best gas detector proved to be the Pieler lamp, which showed readily from 0.25 to 2.5 per cent. of gas. For gas percentages varying from 2 to 4.5 the Wolff lamp is recommended, and for gas varying from 3 to 6 per cent. the Mueseler lamp.

The use of powder or of explosives of similar composition proved to be very dangerous even when used in the form of water-cartridges. With regard to the dangerous use of open lights, it is shown that of the 64 per cent. of explosions found to be due to the use of lights, 49 per cent. was due to the use of the open light. The Marsaut lamps

proved to be the safest, and with reference to the locking arrangements of safety lamps, the magnetic attachment of the Wolff benzine lamp appeared to be distinctly better than any hitherto suggested. Explosions can only be avoided by the use of high explosives combined with a good central friction fuse, or with the Lauer, or the electric fuse. Sand and water-cartridges are also recommended; and chemical and mechanical methods for bringing down the coal instead of explosives are also considered. With regard to ventilation, the air supply should not be less than 565 cubic feet per man per minute, while, if much gas be present, it should be at least double this quantity. The percentage of gas in the return air should never exceed 2, and the ventilation should allow 53 cubic feet of air per minute per ton of coal raised in the twenty-four hours.

Loading Coal.—A device for loading coal into railway vehicles, which is used at several collieries in the west of the United States, consists of a shoot which is caused to vibrate rapidly by means of an engine at the side. The coal is thus delivered uniformly over the vehicle, and is at the same time thoroughly mixed. It is found that there is less breakage than with hand-filling, and the driver can load the coal uniformly by suitably proportioning the speed of his engine. The distributor weighs 6750 lbs., and is driven by an engine having two 10 by 12 inch cylinders.*

In an arrangement for screening and loading coal into vehicles devised by Mr. T. B. Murphey, the several screens are superimposed, and deliver the different sizes into different waggons. The coal is brought in the mine waggon on an overhead track, and discharged on to the screens.†

The International Colliery, Cape Breton.—A full account of the International Colliery at Bridgeport, Cape Breton, is given by Mr. C. B. Kingston.‡ The Upper or Harbor seam only is worked. It dips east at 5°, and was originally worked from a pair of inclines, but a shaft has now been put down. The workings are on the pillar-and-stall method, the stalls being driven six yards wide, with seven-yard pillars cut across every twenty yards by cross-cuts seven feet wide. The coal

* *Engineering News and American Railway Journal*, vol. xxvii. p. 44, with illustrations.

† *Scientific American*, vol. lxi. p. 34, with illustration.

‡ *Transactions of the Canadian Society of Civil Engineers*, vol. v. pp. 19–30, one plate.

is worked in blocks six hundred feet long, by levels turned off from a single pair of inclines. The coal is undercut four feet and sheared in the centre of the stall, and then blown down with powder, one face being kept two feet in advance of the other to diminish the shearing required. The coal is taken to the inclines by horses, and up them by a main-rope system of haulage. Iron tubs, holding 1800 to 2000 lbs. of coal are used. A tail-rope system of haulage has also been recently installed in another part of the mine to increase the output. The shaft is only eighty feet deep; but as it was sunk into the old workings, very heavy timbering was required to compensate for the absence of a shaft pillar. Furnace ventilation is employed, as gas has only been met with in small quantities. A lodgment for the water is provided in each landing or panel, and during the night the water is allowed to flow to the sump from each block, and is then pumped, part of the pipes being made of wood, as the water is very acid. Pyrites is picked out at the tippler shoot, and the coal can be passed over screens.

The Gowrie Colliery, Cape Breton.—At the Gowrie Colliery, Cape Breton, one seam about five feet thick is worked. One shaft, 210 feet deep, used for pumping, is situated near the coke-ovens. A second shaft, 264 feet deep and $11\frac{1}{2}$ feet in diameter, is used for winding. The cages are single-decked, and carry tubs holding 24 cwt. The underground workings are laid off into three sections, and the coal is holed under for three feet, sheared and wedged down. Animal and power haulage is used. For ventilation there is one intake and two upcast shafts, and furnace ventilation is employed. At the surface there are three screens, 18 by $6\frac{1}{2}$ feet, sloping at 30° .*

Coal-Mining in India.—A statement has recently been published † by a committee of colliery managers and others who met on July 22, 1891, of the reasons why they consider mining legislation in India would be at the present stage of the industry very prejudicial, not only to that industry, but also to affiliated industries. This protest was entered against a proposed Coal Mines Regulation Act, and is of interest as it shows the conditions of labour and of the industry generally. In the pits, children of both sexes, women, and men, are employed to the number of 2000, 4000, and 10,000 respectively in the

* *Colliery Guardian*, vol. lxii. p. 1014.

† *Indian Engineer*, vol. xii. pp. 12-14.

Raneegunge Subdivision alone. At the present time it is very difficult to get a sufficient number of labourers, and the rate of wages is very low. As for the men, there is absolutely no restriction; they work when and how they like and for very short hours. The question of women and children as wage-earners for the family is discussed.

The pits themselves are very shallow, the average being 120 feet, and only one in Bengal exceeding 400 feet. Only one seam is worked from one set of pits or inclines, and of fire-damp there is none, or but very little. The seams are generally from 10 to 20 feet thick and can easily be ventilated. Falls of roof and sides are rare.

Alfreton Colliery.—Some notes on Alfreton Colliery are given by Mr. M. Deacon.* There are two tubbed shafts, 153 yards deep, and the output is 700 tons per day, but the engines are capable of winding 1200 tons in $8\frac{1}{2}$ hours. A Walker-Guibal fan is employed for the ventilation. The cleaning belt is 208 feet long and 4 feet wide, and a large number of pickers have to be employed, as the coal is full of pyrites. Not much water has to be pumped, but owing to the variations in the inclination of the seam, an elaborate system of syphons is in use to deal with the water underground. The seam is 2 feet 9 inches to 3 feet 8 inches thick.

The Stanton Ironworks Company's Collieries.—Some notes on the collieries of the Stanton Ironworks Company, given by Mr. J. C. B. Hendy,† deal very fully with the various pits and the plant in use. The royalty comprises 7000 acres, and the collieries employ 1700 men and boys and 150 horses. The output is 700,000 tons. Two seams at a steep inclination are worked at Silver Hill, and one seam at a smaller dip at Teversal and Pleasley. Sections of the seams are given. Details are given for the several collieries of the shafts, ropes, cages, tubs, winding-engines, boilers, fans, electric and underground haulage, pumping plant, &c., &c. At the latter two collieries Waddle fans are in use, and a number of experiments have been made with these fans in June 1891, and with a Capell double-inlet fan at Silver Hill. The coal-cleaning plant is described at some length, and also the electric underground haulage at the Pleasley colliery.

The Havré Colliery, Belgium.—A detailed description is given ‡

* *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 158-159.

† *Ibid.*, vol. ii. pp. 531-552.

‡ *Colliery Guardian*, vol. lxi. pp. 60 and 149.

of the Havré colliery in Belgium. There are three tubbed shafts 9 feet 10 inches in diameter, of which two are used for winding. Two faults with a throw of 33 feet traverse the district. The seams have a mean dip of 20°, and yield coal varying between bituminous and semi-bituminous. Twelve seams have been cut with a total thickness of 23 feet. The shafts were sunk near the eastern boundary by the Kind-Chaudron system. Rock-drills were employed in driving the main roads, and for timbering iron girders of H section are used. The coal is worked to the rise, and the full tubs are braked down the incline. The empty tubs and any material required for stowing are hauled up the incline by a winch worked by a compressed air engine. When the seam dips at 40° or more, the coal is sent down shoots made of boiler-plate. In the shafts iron guides are used, and there are safety catches on the cages. The cages have three decks, and carry two tubs on each deck. The three decks are loaded simultaneously at the bottom, but only two decks can be handled at once on the surface. The pit-heads are of iron, and the winding-engines are fitted with Kraft valve-gear. Flat ropes tapering in width are used. Ventilation is partly natural, but is assisted by a 30-foot Guibal fan. Safety lamps are not employed, but in their place oil lamps are used.

IX.—COAL-WASHING.

Screening Plant at the Bascoup Colliery.—The third installation of screening plant put down at the Bascoup colliery in 1880 is described by Mr. H. W. Hughes.* The building is in three stages; on the upper stage the tubs are handled, on the middle stage the coal, whilst the third stage is the railway floor. The full tubs are taken by creeper chains on four lines from the shaft to side-tiplers, from which they emerge on the opposite side. The tiplers work automatically by means of a self-acting brake, which has only to be released by the workman. Briart screens are largely used. In this form of screen the alternate bars each form a set, and both sets are movable, being supported by cranks at the lower end and by driving eccentrics at the upper end. The arrangement is such that each set in its forward movement is raised above the other set of bars; and as both sets have this movement, the coal is carried forward at twice the rate that it was in the first arrangement, where one set was

* *Journal of the British Mining Students*, vol. xiv. pp. 60-78, six plates.

fixed. To economise power, the eccentrics have been replaced by elbows, so that the two sets balance each other. A further modification consists in the use of perforated bars of channel section in place of the ordinary straight bars. To regulate the size of the coal the bars are made adjustable, the adjustments being made without stopping the screens by a most ingenious device. This consists of a right and left hand screw sleeve between each pair of bars and a feathered shaft passing through the sleeves. By turning these shafts, each pair of bars is drawn together or separated equally, and the shafts can be worked while the screen is in motion. Although the cost of these screens is high, the repairs are low and the results are excellent.

Shaking shoots at an angle of 20° take the coal from the screens to revolving picking tables, whence it is removed by a rake. Loading shoots of semi-cylindrical form and counterbalanced are used; they are made adjustable in length, and are kept full of coal to avoid breakage. In the first and second divisions of the plant the Briart screens are used for making five sizes of coal. Weighing-machines are placed at the loading-points and the tracks for the waggons are on inclines. The small coal which is to be washed is divided into four sizes by a shaking table consisting of four superimposed screens. Felspar and nut-washers on the Coppée system, capable of treating forty tons per hour, are employed. Further details, especially of these Briart screens, are given in a subsequent communication by the author.*

Screens at the Levant du Flenu Collieries.—The screening arrangements at the Levant du Flenu collieries in Belgium are capable of dealing with 600 to 700 tons of coal in ten hours. The screening device consists of two superimposed screens, both 15 feet long by 4 feet wide. The upper screen is composed of bars set $\frac{1}{2}$ inch apart, centre to centre, and the lower is of steel plate perforated with half-inch holes. The screens are hung by two pairs of rods at an angle of 13° , and are vibrated at a low speed by a connecting-rod. Three sizes are made, and the coal is received from the screen on two travelling belts which deliver it into trucks. The belt for the larger size is adjustable in height at the tail end, so that the coal is not broken by falling into the waggons.†

* *Journal of the British Society of Mining Students*, vol. xiv. pp. 147-163, illustrated.

† *Colliery Guardian*, vol. lxiii. p. 609, one illustration.

Coal Cleaning.—A description is given * of the coal-cleaning plant recently erected at the Dechmont colliery, near Newton. The coal is emptied from the tubs by three tippers, each of which serves a shaking screen over which the coal is spread by a distributing belt. The large coal passes over a picking belt to a screen and the waggon shoot. Dirt with adhering coal is hauled in tubs to a crusher, and is treated with the coal which comes through the screens. The small coal is lifted by an elevator and screened into three sizes. The smaller size is washed in a conical washer with revolving arms, the two larger sizes being washed in bash washers.

In the course of some notes on the Stanton Ironworks Company's collieries, Mr. J. C. B. Hendy † gives descriptions of the various plants used for cleaning the coal. At the Pleasley colliery there are two old belts, 110 by $2\frac{3}{4}$ feet and 150 by 3 feet respectively, kept in reserve, and a new belt 200 feet long by $4\frac{1}{2}$ feet wide has been erected. This belt runs at 65 feet per minute and deals with 180 tons per hour. An elevator, also $4\frac{1}{2}$ feet wide, is used in connection with this belt, and both are driven by an engine with a cylinder 16 by 30 inches. The screen is 4 feet wide with a fall of 6 inches per foot, a perforated plate above the screen taking out the dust. At the foot of the screen a belt 24 by 4 feet deals with the cobbles. Double side-revolving tippers are employed, and creepers are used to move the trucks. The whole of this plant is roofed in. The cost of labour has been reduced to $\frac{1}{2}$ d. per ton, and the cost of banking, sorting, cleaning, and screening is 3d. At Teversal a belt 160 by $4\frac{1}{2}$ feet wide has been erected, the construction being similar to that above. Two similar belts have also been put down at the Silver Hill colliery. A jigging screen with a fall of 3 inches per foot is in use and makes 120 vibrations per minute. The cost from banking to screening has been reduced to $4\frac{1}{2}$ d. per ton in one plant and $2\frac{1}{2}$ d. in the other, the output being 300 tons daily in each case. Details are given of the sizes and construction of the various plants.

At the last-named colliery a Robinson washer dealing with five tons per hour is in use.

A method ‡ which has been devised for the separation of slate from fine coal consists in passing the mixture over an inclined shaking sieve. The material passing through this sieve falls into a receptacle provided

* *Colliery Guardian*, vol. lxiii. p. 1026.

† *Transactions of the Federated Institution of Mining Engineers*, vol. ii. pp. 531-552.

‡ *Chemiker Zeitung*, vol. xv. p. 1025.

with an inclined back and with an open horizontal partition in front. The heavier material—the slate—sinks to the bottom of this receptacle, and is removed through an orifice at its base by a horizontally moving finger, while the fine coal passed over a lip above this orifice into a separate receptacle.

Coal-Washing Plant.—At the Simon pit, at Rossitz, Moravia, a coal-washing plant is erected which comprises two Karlik pendulum separators, the one feeding into the other. The large coal passing over the coarsest screen of the upper of these separators is hand-picked and passes over belts direct to the waggons; the other larger sizes of coal are treated in a similar manner. The smaller sizes are jigged.*

The Lührig process for cleaning coal is described by Mr. P. Bateson † as a gradual reduction process, consisting essentially of the following steps: dry separation of the run of the mine, breaking the larger pieces containing shale or pyrites, sizing the coal from four inch downwards in screens, washing the different sizes separately, recovering fine coal from the dirt by further crushing and washing, washing the fine coal from $\frac{3}{8}$ inch downwards, recovery of the sludge or fine coal, clarifying the water, automatic transporting and storing arrangements, and the recovery of by-products. The cost of washing at Motherwell is stated to be one halfpenny per ton for labour, and slack formerly sold at 6d. per ton is washed and sold at 3s. 6d., the ash being reduced from 23 to $2\frac{1}{2}$ per cent. The water used is given at 15 cubic feet per minute for a plant treating 800 tons per ten hours. Except the finest material, the washed coal does not contain an excess of moisture owing to the careful draining. Sulphur is eliminated in the process of washing, but the nitrogen in the coal is hardly affected. The economy of washing coal is then discussed by the author, who shows that there is a large saving owing to the decrease in the amount of coal to be put into the furnace and in the ash to be removed. As there is much coal that can be saved, the subject of coal-washing has a great bearing on the question of the duration of the coal supply.

An illustrated description is given by Grey of the Karwin collieries and coal-washing plant in a note communicated by Rateau ‡ to the Société de l'Industrie Minérale. The two washeries are on the system

* *Die Kohlenaufbereitung*, by R. Lambrecht; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxv. p. 541, with sheet of illustrations.

† *Journal of the Society of Chemical Industry*, vol. x. pp. 984-988.

‡ *Société de l'Industrie Minérale, Comptes Rendus Mensuels*, 1891, pp. 241-247, two plates.

of Schüchtermann and Kremer. They contain four coarse jigs for the slack. The water passes through spitzkastens, and the products are treated on felspar washers, which will reduce the ash to 4 to 6 per cent. As, however, stronger coke can be made if the ash is 10 per cent., and this coke fulfils all requirements, the use of the former has been discontinued. In the jigs used, the piston is small compared with the washing sieve, which is inclined, the pyrites with the slate collects at the lower end, whence it is removed through a sliding door, and large masses which cannot get through are removed every twenty-four hours, when the dirt is sluiced from the bottom of the box. The pyrites is collected and washed in separate jigs on a bed formed of the larger lumps, and a fine product containing 43 to 45 per cent. of sulphur is obtained. The diminution in the quantity of coal by washing amounts to 18 per cent., but 100 tons of pyrites are saved per month and sold at 17s. 6d. per ton. The cost of this washing plant was £760, and the annual cost is £113, so that an annual profit of some £688 is made at this price.

Illustrations are given * of a coal-washing and separating plant erected at Zollern, near Dortmund, to treat 80 tons of coal daily. The result of the working is:—

	Per Cent.
Lump coal above 3 inches	9·8
Nuts between $1\frac{1}{2}$ to 3 inches	4·9
Nuts between $1\frac{1}{4}$ to $1\frac{3}{4}$ inch	6·8
Nuts between $\frac{1}{2}$ to $1\frac{1}{4}$ inch	8·8
Nuts between $\frac{3}{8}$ to $\frac{1}{2}$ inch	8·8
Coking coal under $\frac{3}{8}$ inch	50·0
Dirt and sludge	10·9
	100·0

The washed coking coal contains as an average 5·6 per cent. of ash, being reduced from 13 per cent., and the water consumption is 11 per cent. The coal is emptied from the tubs by a tippler on to a screen which consists of longitudinal bars below which are a set of rollers driven by chain-gearing. Lump coal above three inches passes over this screen and is hand-picked on belts. The coal which passes through this screen is taken by a conveyer to other screens where it is sized as above and sent to the washing-machines. Small coal below three-eighths of an inch is further sized to one-eighth, one-fourth, and three-eighths in revolving screens before washing.

Coal-Washing and Briquette Plant for Asia Minor.—Extensive coal and iron-ore fields exist in the province of Heralia, on the

* *Engineering*, vol. liii. pp. 132-133.

southern coast of the Black Sea, and a plant for washing the coal and for making briquettes has recently been sent out. The coal is brought in the mine waggons to the top of the building, where it is discharged into a hopper, whence it is passed over screens. The smaller coal is crushed, divided into two grades in a revolving screen, and washed in jigs. The washed coal, as it is thrown out of the washers, passes over a draining screen, and is taken along an iron trough by a conveyer. This trough is suspended over a flue so as to dry the coal before it is mixed with the pitch and made into briquettes.*

The Manufacture of Patent Fuel.—According to Mr. J. Clark,† the first recorded attempt to introduce the manufacture of agglomerated fuel into England was in the year 1594, when Sir Hugh Platt published a work entitled, “A New, Cheap, and Delicate Fire of Cole Balls.” He describes his project as one to sweeten sea-coal, so as to make it a substitute for wood in domestic economy, by mixing loam with the pulverised coal. There are about 385 specifications relating to patents for inventions of artificial fuel made from small coal between the years 1799 and 1885, and of all the materials tried, pitch remains the only one in regular use.

At Ormiston Station colliery a small plant for the manufacture of patent fuel was erected two years ago, and is described in detail by the author. The coal and pitch are ground together in a disintegrator, and are stirred and heated to the proper consistency for compression in a pug-mill. The mixture is received in a pan-mill with revolving arms in it to fill the moulds, and the blocks are compressed in a press-cylinder under a pressure of 12 cwt. to the square inch of block surface. The whole of the machinery is driven by a pair of coupled engines with 10-inch cylinders and 20-inch stroke, supplied with steam at 40 lbs. pressure. The speed of the engine is 60 revolutions per minute, and that of the main shaft of the full plant is 95 revolutions per minute. The machine turns out three tons of fuel per hour, the quantity of pitch used being 9 to 10 per cent. of the finished fuel. The size of the briquette made is 6 by 4 by $3\frac{1}{2}$ inches, and its weight is 4 lbs.

* *Engineering*, vol. lxxiii. p. 158.

† *Transactions of the Mining Institute of Scotland*, vol. xiii. pp. 236-241, with folding plate.

PRODUCTION OF PIG IRON.

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I.—BLAST FURNACE PRACTICE.

The First Iron Blast Furnaces in America.—In connection with the paper by Mr. W. H. Adams * showing the pioneer work done by the Spotswood furnaces in Virginia, Mr. E. C. Pechin † regards it as a point of great interest that these early furnaces were established for the purpose of working the “gossan” ore, which forms the oxidised cap of the deposits of cupriferous iron pyrites. This gossan ore has been largely ignored as a material for the manufacture of iron. In Floyd county there are the remains of an old furnace which ran entirely on this gossan ore, the produce exhibiting remarkable tenacity, possibly on account of the small percentage of copper present.

At the Pulaski furnace foundry iron of excellent quality is being made from a mixture of 30 per cent. of gossan ore with the brown iron ore of the region.

History of Cast Iron.—In his treatise on the ironworks of the Haina monastery in Hessen, L. Bickell ‡ stated that the working of the iron-foundries in that locality probably dated back much farther than 1555, the date of the earliest works-account preserved. A confirmation of this statement is afforded by a recently discovered inventory of guns belonging to the Prince of Hessen, 1544, showing that at that

* *Journal of the Iron and Steel Institute*, 1891, No. II. p. 233.

† *Transactions of the American Institute of Mining Engineers*, Cleveland meeting (advance proof).

‡ *Berg- und Hüttenmännische Zeitung*, vol. li. p. 38.

time the Prince possessed a large number of cast iron guns. This would indicate a foundry industry of still earlier date.*

Blast Furnace Plant, Equipment, and Design.—Some of the more recent changes and features of blast furnace plant, equipment, and design, are described by Mr. H. Pilkington,† and compared with old-fashioned practice. Furnace sites are now preferably chosen with a view to the ready removal of the products, good access, ventilation, and drainage. Lifts are generally used to take materials to the top of the furnace, and the old hill-side situations formerly good for this object are now not used. The bottoms of the furnaces are raised to get the trucks under the tapping holes and level with the pig beds. The furnaces are built farther apart, so as to give more space for all the subsidiary appliances. Several lines of railway should be placed behind the furnaces, so as to load the barrows direct from the trucks, and this is quite as economical as is the use of bunkers, but the latter give storage capacity. Kilns for calcining ore should be as near the furnace as possible, but blackband ore or tap cinder is preferably calcined at the point of production. American practice is making itself more and more felt in this country, and in time a separate plant will probably be attached to each furnace. Gas-flues are preferable to overhead tubes for supplying the stoves. The correct method of the application of gas to boiler-firing is of great importance, but has been somewhat neglected. To properly utilise the gas, it should be burnt in a preliminary combustion chamber, and not directly under the boilers. More economical boilers are required when the gas is poor or scanty, as all the power necessary should be obtained from the gas. Considerable economy can also be effected by using properly designed blowing-engines. Of the several forms of brick stoves in use, the Whitwell stove is extensively adopted when the gas is very dusty, as in the manufacture of ferro-manganese. By an arrangement of valves the current is directed alternately through the different passages in the Ford and Moncur stove, which is thus efficiently cleaned if the reversals are done systematically. The author's experience is confined to Cowper stoves with Lister instantaneous relief valves. These have replaced the cleaning and manhole doors, and one is placed on the gas

* According to Smiles, the first cast iron cannon of English manufacture were made at Buxstead in Sussex in 1543 by Ralph Hoggs, who employed as his principal assistant one Peter Baud, a Frenchman, who introduced the manufacture from France.

† Paper read before the South Staffordshire Institute of Iron and Steel Works Managers, November 7, 1891.

valve-box, so that the stove is cleaned by relieving the blast at each reversal. The practice is also to raise the supporting columns, so as to afford more ready access under the stove. Water-cooled slides and seatings are much used, but the valves which give least trouble are those which contain plenty of metal, the slides being often made six inches thick. Fewer expansion drums in the hot-blast pipes can be used if the pipes are well lined with brickwork.

The modern practice in the construction of the furnace itself is to have an iron-cased shell supported on columns, 18 to 20 feet high, with lintel plates sufficiently strong to take the whole weight of the lining and superstructure, thereby relieving the hearth. The weight of the bell and other top fittings is also taken off the lining by brackets attached to the casing. The blast mains are usually carried outside the columns. The thickness of the brickwork is reduced, cooling plates and cooling blocks near the tuyeres, and other means are used to preserve the shape of the furnace. The use of the supporting columns aids this, as the thickness of brickwork necessary at the boshes is reduced, and the air-cooling is more efficient. The hearth is better preserved by enlarging it, and by always keeping some metal on it. The tapping-hole and slag-notch should be midway between two tuyeres. By the use of large flues and down-comers the dust is more completely caught. The bell ought to be exactly in the centre of the furnace, but in this country means for lowering it centrally have not been so extensively adopted as in America.

Improvements in Blast Furnace Construction.—F. W. Lürmann * refers to various modern improvements in blast furnace construction, such as cooling arrangements and the use of metal supports for taking off the weight of the superincumbent brickwork and of the heavy metal work at the top of the furnace from the brick lining. He illustrates another such iron arrangement which he has introduced at the throat of several furnaces, and which entirely replaces the brick lining at the point of its greatest wear, near the cone, and which bears the weight of the gas-withdrawal pipes.

Dr. F. C. G. Müller † discusses by the aid of diagrams the question of furnaces with partial regeneration of the combustion products, and he instances the new Siemens furnace as described by Messrs. Head and Pouff ‡ as the type of a successful furnace, though he refers to

* *Stahl und Eisen*, vol. xii. pp. 221-223.

† *Ibid.*, vol. xi. pp. 969-977.

‡ *Journal of the Iron and Steel Institute*, 1889, No. II., p. 256.

some points in the description * as requiring elucidation. In conclusion, he observes that it is practically certain that no further great improvements in furnace construction are to be looked for, as some furnaces now burn the coal almost completely to carbonic anhydride and water, and cause the waste gases to pass to the stack at a temperature not exceeding 300°. Loss of heat there may be, but the limit of practical economy appears to have been reached.

The Hanging-up of Charges in Blast Furnaces.—Of the disturbances which occur in the working of blast furnaces, the stoppage of the charge during its descent is one of the most frequent. The causes of this are discussed by Van Vloten.† The hanging-up of the charge consists in one portion of the furnace contents adhering to the furnace-side, and so preventing the descent of the remainder of the charge above it, the lower part of the furnace gradually becoming empty. In some cases the furnace takes almost its ordinary quantity of blast, the flame at the throat being scarcely changed, only slightly purer and more transparent. In such instances a momentary stoppage of the blast by removing the upward pressure below the stopped charge is sufficient to cause the downward pressure of the superincumbent charge to exert itself and so remove the obstruction. It frequently happens that this slight stoppage repeats itself at rapid intervals, and growing worse, finally almost chokes the furnace, shutting off the blast ceasing to effect an improvement. The furnace then takes a much smaller quantity of blast, there is very little slag, and it consists mostly of dust and nodules, the flame at the throat is slight, transparent, free from smoke, of blue or blue-red colour, and the gas is completely free from dust. In this case it is best to use a colder blast than usual. This soon causes a good effect, and it will become possible to bring the charge down by shutting off the blast.

Finally, the choking-up of the furnace may become so bad that scarcely any gas can penetrate the charge. The furnace then takes very little blast, the back pressure being almost as great as the blast pressure, and when the blast is turned off the furnace gas escapes with violence through the tuyeres, a flame at the furnace-throat being no longer observable. In such a case, the small quantity of gas which does pass through the charge is incapable of being ignited, and fluid slag is no longer formed. In such a case blowing-in cold blast can

* *Journal of the Iron and Steel Institute*, 1889, No. II., p. 256.

† *Stahl und Eisen*, vol. xii. pp. 114-118.

evidently be of no avail ; but if a hole is made in the crucible such as that left by removing one of the tuyeres, and the blast then turned on, this can now exert an action, blowing out the charge below the choked part. In the course of hours, the bottom portion having become emptied, the choked part gradually falls down bit by bit, gas begins to penetrate the charge, slag forms again, and finally the block is altogether removed. Increasing the pressure of the blast also does good. Bad coke is a frequent cause of this hanging-up of the charges, as also is the use of fine wet ores or very hot blast. These stoppages only take place when the furnace is working fairly well, and never when the working is irregular. In the furnace on which the author's observations have been made, the point at which this choking takes place lies very deep, between the crucible portion and the boshes. The author believes the cause to be due to the exceptionally large quantity of voluminous carbon which becomes deposited under certain furnace conditions in the midst of the charge, the formation of bears in the lower portion of the furnace facilitating the setting of the charge.

Messrs. J. T. Erpf and Co.* criticise the above deductions of Van Vloten, especially as regards the stoppage being due to the deposition of carbon. Working with small charcoal furnaces, they have found that these stoppages have occurred during slight increases in the temperature of the blast, or when using more blast and smaller tuyeres. In these cases they think that the cause of the hanging-up of the charge was due to the fact that, consisting of roasted quartzose spathic ores, the charge began to fuse and clot too soon, and that, owing to the pressure of the descending charge, the mass caked together, and finally caused the stoppage.

The Destruction of Blast Furnace Linings.—F. W. Lürmann † discusses the question of the lining of blast furnaces. This lining is worn away owing to one or other of the following causes :—(1.) Actual wear produced by contact with the descending charge ; (2.) By the action of the constituents of the blast furnace gases, especially of cyanogen or of its salts ; (3.) By the action of sodium chloride contained in the coke ; (4.) By flaking owing to the deposition of carbon from carbonic anhydride, caused by the iron particles formed from the iron pyrites existing within the material forming the lining. The first of these only accounts to a slight extent for the wear actually observed,

* *Stahl und Eisen*, vol. xii. pp. 336-338.

† *Ibid.*, vol. xii. pp. 265-268.

and although the action of the cyanogen or volatile alkaline cyanides is likely to account for a considerable portion of the destruction, yet this still requires experimental proof. The water used for cooling purposes takes up large quantities of cyanides from the walls of blast furnaces, and fused cyanides may even be occasionally observed to drop away from such walls. The third source of wear, the salt present in the coke, is undoubtedly an important cause. Coke-ovens are frequently rapidly destroyed by the salt present in the coal coked, the quantity of this salt having in one case, to which the author refers, reached as much as $48\frac{1}{2}$ lbs. in the charge of six tons of coal. An examination of the coke recently charged into a blast furnace showed it to contain 0.062 per cent. of sodium sulphate and 0.119 per cent. of sodium chloride, or for 100 tons of coke nearly 140 lbs. of the former and over 260 lbs. of the latter; and quantities such as these charged daily into a blast furnace would soon exert a marked destructive action on the lining. The fourth cause of wear is a most important one when, as is nearly always the case, the fire-resisting material used in the manufacture of the furnace lining contains iron sulphides. These lead to the formation of metallic iron, which in turn causes the deposition of carbon within the masonry, which then splits away and is destroyed. The author recommends the use of carbon bricks.

K. Sorge * questions whether the lining of blast furnaces should be of fire-resisting brickwork. He concludes that this is not necessary, and that instead of such a mass of brickwork as is usually employed, a sufficiently strong iron casing well cooled with water is all that is really necessary.

Metal Jacketing for Blast Furnace Hearths.—The various forms and materials which are used for building or covering the outside walls of the hearth of the blast furnace are discussed by M. Boivin,† who proposes a new form of metal jacketing. This consists of a number of curved segments, 39 inches long by 19 inches high by half an inch in thickness, and weighing about 1100 lbs. each. They are built up round the furnace so as to break joint, and are secured together by the aid of specially shaped keys, which fit into circular and straight slots in the sides and corners of each block. The

* *Stahl und Eisen*, vol. xii. pp. 263-270.

† *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, March 1892, pp. 73-78, one plate.

joints between the plates are somewhat hollowed on the exterior, so as to be packed with some refractory material.

The Dowlais Cardiff Furnaces.—An illustrated description has recently been given* of the blast furnaces erected by the Dowlais Iron Company at Cardiff, where it is intended to produce mild steel by the open-hearth process. The works will occupy an area of 160 acres. There are three blast furnaces, each 75 feet high, 20 feet in diameter at the boshes, and 10 feet in the hearth. Water-cooled boxes are built into the boshes and hearth. The blast is supplied by eight Cowper stoves, 68 feet high and 24 feet in diameter, with a heating surface of 47,500 square feet. The ore for each furnace is stored in three bunkers at the back, holding 2600 tons each, and the limestone in a fourth bunker holding 850 tons. The bunkers are filled from an overhead track and a large gantry. A coke-bunker for each furnace supplied by a branch gantry holds 1250 tons, but these are mainly used as reserves and the furnace charged from the maker's waggons. The furnaces have closed tops with cup-and-cone chargers, and the gas is taken off by a single down-comer to cylindrical dust-catchers and thence to the gas mains. Twelve double-flued Lancashire boilers, 30 feet long and $12\frac{1}{2}$ feet in diameter, have been erected, and can develop 250 horse-power each at 100 lbs. pressure. The blast-engines are direct acting, with the blast below the steam-cylinders. The air-cylinders are 88 inches in diameter, the high and low pressure steam-cylinders, 36 and 64 inches, with a common stroke of 60 inches. Each engine develops 1200 horse-power and can deliver 25,000 cubic feet of air at $4\frac{1}{2}$ to 10 lbs. pressure. Pumping machinery for the lifts is also provided. As the output will be 800 to 900 tons weekly, the pig beds are large, and are served by a travelling crane on a girder of 100 feet span, which takes the pigs with the sow to a hydraulic breaker. The slag is removed in small ladles, which tip it sideways on to the ground on the American system.

Blast Furnace Practice in the United States.—A series of notes on blast furnace practice in the United States are given by Mr. W. Colquhoun,† from data obtained during the recent visit of the Iron and Steel Institute. The notes deal with the general form of the

* *Engineer*, vol. lxxii. pp. 396 and 404.

† *Proceedings of the South Wales Institution of Engineers*, vol. xvii. pp. 247-264, eight plates.

furnace and the other plant, attention being given to the production and cost. An appendix contains a tabulated statement of several furnaces, and a comparison of profit on English and American practice, which shows returns of 4·2 and 3·78 per cent. respectively. Illustrations are given of furnaces, a slagging valve, bell and hopper downcomer and dust-catcher, stove bricks, and a 10-ton tipping slag ladle.

Mr. J. M. Hartmann * states that at the Franklin blast furnace a fossiliferous hæmatite ore is smelted with Pennsylvania anthracite and Connellsville coke. The furnace has a capacity of 6731 cubic feet, and 10 tuyeres $4\frac{1}{2}$ inches in diameter, placed 6 feet above the hearth, which is 10 feet 6 inches in diameter. There is one slag notch 4 feet above the bed. The furnace is worked by two blowing-engines and three firebrick stoves. For the year 1889 this furnace shows the following record, the fuel used being a mixture of one-third anthracite and two-thirds coke :—

Fuel per ton of iron, lbs.	3091
Ore per ton of iron, lbs.	5376
Limestone per ton of iron, lbs.	1485
Pig iron made per week, tons	583
Mean temperature of blast	1250°
Maximum temperature of blast	1350°
Average air per minute, cubic feet	16,000
Maximum air per minute, cubic feet	18,100
Average pressure, lbs.	9½
Air per minute per 1000 cubic feet capacity, cubic feet	2277

In the month of January 1892, blast furnace I. of the Edgar-Thomson steelworks made 12,706 statute tons of pig iron, the best week's work amounting to 3005 tons, and the best day's to 511 tons. The average fuel consumption was 1700 lbs. This is stated to exceed any previous blast furnace record.†

New American Blast Furnaces.—A new coke blast furnace was recently blown-in at South Chicago, Illinois. It is 80 feet in height and 17 feet in diameter at the boshea. The shell is of steel. The tuyeres are seven in number. All the gas mains are overhead. There are three firebrick stoves of the Cowper-Kennedy type, each 18 by 75 feet. The draught stack is of iron, 192 feet high and 12 feet in diameter, lined with firebrick. A double vertical hoist is used for the stock, and the furnace top is of the ordinary cup-and-cone type

* *Iron Age*, vol. xlviii. p. 541.

† *Ibid.*, vol. xlix. p. 257.

with steam-lift. The furnace is served by two twin vertical blowing-engines, fitted with the Nordberg-Corliss valve gear. The blowing cylinders are 84 inches in diameter with 60-inch stroke, and the steam-cylinders 40 inches in diameter with 60-inch stroke.*

Mr. E. C. Pechin † gives a list of blast furnaces in Virginia which are thoroughly modern, well equipped, and capable of a large output. Each one has an average yearly output of 30,000 tons, so that, with all the furnaces in blast, the district has a yearly production of 390,000 tons.

The average yield of the ore mixture in the district has been about 42 to 44 per cent. Though, in the author's opinion, there has been abnormal activity in furnace construction as compared with the mines opened up, still he is of opinion that, in a short time at least, the ore supply will be quite equal to the demand.

Another blast furnace at Girard, Ohio, is being reconstructed. Originally the stack had the dimension 18 feet by 76 feet. The new furnace will be 80 feet in height and 20 feet wide at the boshes. Its capacity will probably be 250 tons of iron a day.‡

The No. 2 Swede blast furnace at Swedeland, Pennsylvania, has recently been blown-in.§ It is 80 feet in height and 15½ feet wide at the boshes, with an estimated capacity of 950 tons of iron in a week. It is equipped with three Taws-Hartmann firebrick stoves, each 70 feet by 18 feet in dimension.

The two blast furnaces of the Powelton Iron Company at Saxton, Pennsylvania, were built in 1881 and in 1887. The dimensions of the older are 70 by 18 feet, and of the more modern one 71 by 17 feet. The first furnace has three 70 by 18 feet Whitwell stoves, and the second, three 60 by 18 feet stoves.||

Blast Furnace Tuyeres.—The Langdon tuyere has been in use for some time at the Port Henry blast furnace, New York. Both the tuyere and the breast are constructed in substantially the same manner. The tuyere consists of a butt and nose joined together either by soldering, brazing, or bolts. An eccentric piece, consisting of concentric shells held apart by bridges, may be interposed between the nose and the butt. This form of tuyere, while showing a slightly

* *Iron Age*, vol. xlviii. p. 494.

† *Iron Belt*, through the *Iron Age*, vol. xlviii. p. 1031.

‡ *Iron Age*, vol. xlix. p. 212.

§ *Ibid.*, vol. xlix. p. 213.

|| *Ibid.*, vol. xlix. p. 119.

higher first cost than in the case of the ordinary form, is stated to show considerable economy.*

A renewable nozzle for a water-tuyere, designed by Mr. S. Keartland, is illustrated in *Engineering*.† By use of this device a burnt nozzle can be removed and replaced without breaking the water connections.

Closed Charging Apparatus.—Tholander's charging apparatus consists of an iron cup bricked in at the top of the blast furnace. On this rests a cylindrical or conical mantle, which is riveted to another cup. The latter carries a closed cone or cylinder, which has in the middle only one small aperture, allowing free passage for the float. The cone is connected to the cup and mantle by means of three chains fastened to its apex, so that if the cone is sufficiently raised, the cup and mantle are carried with it. In the outer cup is placed the ore which is required to fall round the sides of the furnace, and in the inner cup the fuel and the ore for the centre of the furnace. When it is required to charge the furnace, the inner cone is first raised just sufficiently to enable the coal and ore from the inner cup to fall into the furnace. It is then raised higher, so that the outer cup and the mantle on which it rests are raised sufficiently to allow the charge for the sides to fall. In order to keep the ore in its place at the walls, there is inside the furnace top a cylinder serving as guide. This charging apparatus has been found to give very satisfactory results at Avesta in Sweden.‡

Charleville's charging apparatus consists of a ring tapering inwards at its base, and supported above by a flange resting on the furnace top. On this ring is an iron beam carrying a cone, and having passed through its centre a spindle which is connected with a double-conical ring. A rod passing through the cone serves to indicate the height of the charge, and a lever at the top of the furnace attached to the spindle serves to raise or lower the double-conical ring. Below the throat of the furnace there is a conical ring, and above this four tubes for drawing off the waste gases. The charge is placed in the space between the tapering ring and the centre of the double-conical ring, and in that between the latter and the cone. On lowering the double-conical ring the charge falls into the furnace, the material in the outer

* *Iron Age*, vol. xlviii. p. 679, one illustration.

† Vol. lii. p. 460.

‡ *Jernkontorets Annaler*, vol. xlv. p. 184, with illustration.

compartment falling round the walls of the furnace, and that in the inner compartment falling into the middle.*

R. Volkmann † describes a new form of cup and cone. The advantages claimed for this arrangement include a central vertical movement, free from side-motion; an evenly balanced attachment; ready removability; and safety in cases of breakage or explosion.

Blast Furnace Slag Waggon.—Illustrations are published ‡ of a slag waggon, having a capacity of 120 cubic feet. It will hold six tons of slag. Upon a wheeled frame roll three rockers, which are held level by a pin except during the operation of tipping. Upon these rockers is bolted the bottom plate of the waggon, and upon it rests the "tub" or side framework, which tapers towards the top. This tub consists of six castings bolted together. A brick lining may be given to the bottom plate. After the tub has been raised the bottom plate is tipped and the slag readily slips off.

II.—CHEMICAL COMPOSITION OF PIG IRON.

The Control of Silicon in Pig Iron.—Mr. W. H. Morris § gives his experience in controlling silicon in pig iron. By using ores low in silica, and by closely watching the conditions of the furnace, an iron is made running below 0·45 per cent. of silicon and 0·05 sulphur. The best week's work averaged 0·265 per cent. of silicon and 0·05 sulphur, only 7 per cent. of the metal exceeding 0·08 sulphur. This was done with iron stoves, but after remodelling the furnace and using firebrick stoves, a great deal of iron was made with less than 0·10 per cent. of silicon, whilst the sulphur did not exceed 0·017, and phosphorus was as high as 4·5 per cent. The furnace-work must be regular, the ore and limestone uniform in quality and in size, and the fuel should not be high in sulphur. Half-coal and half-coke was found to be best adapted for the particular furnace. If the furnace works slowly, or if there is a stoppage, the silicon is increased, and the same is true in case

* *Jernkontorets Annaler*, vol. xlv. p. 157.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. pp. 553-554, two illustrations.

‡ *Iron Age*, vol. xlviii. p. 117, three illustrations.

§ *Transactions of the American Institute of Mining Engineers*, Baltimore meeting (advance proof).

of a slip with risk of increased sulphur. The sulphur goes into the metal if the furnace is too cold.

Irregular Distribution of Silicon in Pig Iron.—Mr. J. W. Thomas * points out, as the result of a number of determinations, that the metal coming first from the furnace is usually richer in silicon than that which follows. In each pig, too, the percentage varies greatly, being higher at the point of the pig than at the butt. When the iron contained soft grey spots, these spots were richer in silicon than the metal surrounding them.

Manganese and Sulphur in Pig Iron.—The question of manganese and sulphur in pig iron is discussed at some length by Mr. T. E. Holgate.† There is no difficulty in obtaining pig with low sulphur contents when the silicon is high or when good materials are used, but if the materials are poor, much manganese must be present. Basic pig iron should only contain about 0·5 per cent. of silicon and 0·05 per cent. of sulphur. With these amounts the manganese contents need not be great, but above those limits more manganese must be introduced. For each unit of this metal in the pig two or three times as much have to be put into the furnace, and if the ores do not contain it, the extra cost becomes considerable. The action of manganese in the blast furnace is usually considered to be that it combines with silica, leaving some free lime to take up the sulphur, but this is questioned by the author, as lime is the stronger base. Taking the two slags containing—

	I.	II.
Silica	36·0	34·0
Alumina	10·0	10·0
Lime	52·0	49·0
Manganese oxide	...	5·0

the second is the more fusible, and contains more oxygen combined with the bases, and in the production of basic pig iron it is necessary to work with a fusible slag, or else the temperature is high and silicon is reduced. Manganese has a further action, due to its affinity for sulphur and to the slight solubility of manganese sulphide in iron, especially when the metal contains much manganese. On the addition of manganese to the blown metal, it combines with the oxygen and sulphur and removes both of them, displacing the sulphur from its combination with the iron.

* *Iron Age*, vol. xlviii. p. 839.

† Paper read before the South Staffordshire Institute of Iron and Steel Works Managers, March 12, 1892.

The author has examined a large number of spiegeleisens for sulphur, and the highest percentage of sulphur found was 0.02, and then there was only 5 per cent. of manganese present. Mr. S. Sutcliffe has had similar experience. Many of these samples had been made under conditions ensuring a large reduction of sulphur if manganese had not been present, so that its absence may be ascribed to the manganese.

The results obtained by various authorities are quoted, and especially the results obtained by J. Massenez.* Several analyses have been given of iron containing both manganese and sulphur in considerable quantities, but the author is disposed to account for these by the manganese sulphide not separating, owing either to the non-quiescence of the metal or to its inability to do so, from the temperature being too low, or to variations in temperature in the furnace. A large number of experiments were made in the endeavour to obtain an iron rich both in sulphur and manganese by melting together in a crucible iron containing these elements, but without much success, and details are given to show the composition of the metals used and of those obtained. In all cases, except with a very siliceous slag, the sulphur was removed. The method of applying manganese as a desulphurising agent is then described.

Grading of Pig Iron.—In forge pig iron it is customary to make the phosphorus the basis of classification, any percentage below 0.2 being No. I. quality, from 0.2 to 0.8 No. II., and 0.8 to 2.0 No. III., and with over 2.0 per cent. the metal is classed as basic pig iron. Foundry pig iron is classed mostly according to its percentage of silicon and its fracture, and spiegeleisen according to the manganese. This classification is a wrong one; the metal ought to be classed according to its chemical composition.† The following analyses show how greatly this may vary even in metal of the same "grade":—

* *Journal of the Iron and Steel Institute*, 1891, No. II. pp. 76–82.

† *Chemiker Zeitung*, vol. xv. p. 1493.

Foundry Pig Iron.	Graphite.	Mn.	P.	Cu.	S.	Si.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
I.	4.159	1.59	0.057	0.026	0.029	2.55
II.	4.000	0.80	0.100	0.060	0.072	3.50
III.	3.600	0.86	0.300	0.060	0.063	2.50
IV.	4.200	0.59	0.039	0.016	0.036	2.68
V.	3.680	1.80	0.138	0.135	0.050	2.36
VI.	3.750	0.85	0.860	0.037	0.120	2.00
VII.	4.050	0.48	2.280	0.024	0.183	2.26

Nos. I., II., German hæmatite foundry iron No. I.; III., German foundry No. I.; IV., English hæmatite No. I.; V., English foundry No. I.; VI., German foundry Nos. II. to III.; and VII., Luxembourg foundry pig iron.

In forge pig iron these differences are even greater. This is especially the case as regards the percentage of copper. This metal is not eliminated during the puddling, and owing to the loss of metal, its percentage actually increases.

The following are analyses of forge pig iron :—

Forge Pig Iron.	Carbon.	Mn.	P.	Cu.	S.	Si.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
I.	3.972	9.41	0.043	0.450	0.010	0.920
II.	4.320	4.08	0.060	0.032	0.021	0.360
III.	4.095	1.38	0.068	0.044	0.036	0.720
IV.	3.549	1.95	0.144	0.029	0.072	0.219
V.	3.885	3.08	0.120	0.180	0.069	0.690
VI.	4.260	2.07	0.407	0.033	0.038	0.480
VII.	3.840	3.49	0.220	0.024	0.027	0.180
VIII.	3.960	8.43	0.230	0.576	0.011	0.692
IX.	4.093	2.19	0.340	0.160	0.058	0.243
X.	3.834	2.95	0.560	0.026	0.032	0.340
XI.	3.504	0.81	1.610	0.085	0.080	0.180
XII.	2.569	0.13	1.790	0.010	0.370	0.350
XIII.	4.378	0.64	1.620	0.025	0.160	0.840
XIV.	3.840	0.18	1.830	0.480	0.340	0.270
XV.	3.975	1.41	2.920	0.380	0.095	0.301

Nos. I., II., III., IV., V., German forge pig iron No. I.; VI., VII., German forge pig iron No. II.; VIII., Siegen No. II.; IX., X., Rhenish Westphalian No. II. forge; XI., Rhenish Westphalian No. III. forge; XII., XIII., Luxembourg forge; XIV., Belgian forge; and XV., German basic pig iron.

III.—BLAST FURNACE SLAGS.

Composition of Blast Furnace Slags.—B. Platz * observes that in blast furnace slags silica and alumina may replace each other, but not alumina and lime. Further, that the composition of pig iron is always

* *Stahl und Eisen*, vol. xi. pp. 1-8.

dependent on the presence of a certain percentage of lime in the slag, and not on any particular degree of acidity. He gives as examples two slags having the same acidity—monosilicates—but different percentages of lime :—

	I.	II.
	Per Cent.	Per Cent.
Silica	37.1	35.4
Alumina	16.7	9.2
Lime	38.5	47.2
Magnesia	1.9	2.3
Manganous oxide	0.7	0.4
Ferrous oxide	0.4	0.4
Calcium sulphide	4.1	4.6
Totals	99.4	99.5

No. 1 was a glassy slag ; No. 2 an earthy one, rough and granular on the surface. The first could be drawn out into threads when molten ; the second was thin fluid and could not be drawn out. No. 1 on cooling became firm and hard, whilst No. 2 while still warm disintegrated into comparatively fine powder. The glassy slag produced a pig iron richer in silicon and sulphur than did the earthy slag. The temperature of blast and the weight of coke were the same in both instances, and the percentages of iron and manganese in the two charges varied inappreciably. It is a well-known fact that when treating aluminous ores a pig iron may be obtained which contains a high percentage of silicon, and that when spiegeleisen is to be made the slag must not contain much alumina. In the one case it leads to the diminution of silicon, and in the other to the diminution of the manganese.

For two slags with an equal percentage of silica but varying percentages of alumina, that with the excess of alumina is, from a chemical point of view, the more basic. Lime is the material which chiefly causes the “shortness” or absence of fibres in slag. The more lime a slag contains, the finer will be the powder into which it disintegrates.

The author then proceeds to discuss the percentage of lime to be added to the charge, and the mode of calculation. He adds together the percentages of silica and alumina, and multiplies the result by $\frac{5}{18}$. Then from the product he subtracts the percentages of lime, magnesia, and manganous oxide present, and the result is the lime to be added. The following is an example of this calculation :—

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An ore contains—

SiO ₂ .	Al ₂ O ₃ .	CaO.	MgO.	MnO.
8.0	2.0	4.0	0.5	1.0

Then $8.0 + 2.0 = 10.0$; $10.0 \times \frac{5.2}{4.8} = 10.83$. From this is subtracted $4.0 + 0.5 + 1.0 = 5.5$; $10.83 - 5.5 = 5.33$, the lime required to be added. A number of examples are given.

With reference to the disintegration of slags rich in lime, the author observes that while lime itself will remain compact for a week or more, a slag rich in lime has a tendency to disintegrate even before it has become cold. This occurs, however, only under certain conditions. Rapid cooling prevents it altogether; slow cooling, on the other hand, induces it. If a lump of slag breaks or is broken while the central portion is still liquid, it will not afterwards disintegrate; the fluid centre runs out and solidifies to a porous mass, which, in spite of its large surface and consequent increased exposure to atmospheric action, does not disintegrate. The shell, too, remains unacted upon. The limit at which a slag ceases to disintegrate is when the percentage of RO bases reaches 45 or 47. The presence of manganous oxide does not affect the change in the state of the slag, but the presence of much magnesia prevents it. Even slags with a high percentage of lime frequently do not disintegrate, and that without apparent reason. Examples of such slags are the following, which were found to contain—

	SiO ₂ .	Al ₂ O ₃ .	FeO.	MnO.	MgO.	CaO.	CaS.
I. . .	29.4	13.2	0.7	0.4	3.1	48.4	4.5
II. . .	30.9	15.0	0.5	0.8	2.6	44.7	5.0

The author attributes the disintegration in lime slags to the separation of lime and RO bases in the free state during the slow cooling of the slag.

Dr. Kosmann * discusses these observations of Platz as to the way in which the alumina exists in slags, whether as an acid or a base, and is of opinion that alumina can only be considered to be present as a base in mono-silicates. For every higher silicate its action cannot be foretold in advance. The action of alumina, too, is dependent on the temperature, alumina tending to liberate silica with increasing temperature, and thus rendering the slag more acid in its character. The alumina itself perhaps acts as an acid.

F. Toldt,† in discussing the subject of blast furnace slags, refers to

* *Stahl und Eisen*, vol. xii. pp. 270-275.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. pp. 15-20 and 30-35.

the statement of Professor Dürre, that the whole art in the production of good pig iron cheaply, lies in the formation of a suitable slag. The slag should be as easily fusible as can be produced, and the quantity formed should be the smallest possible. A slag must not simply be readily fusible; but it must be a thin fluid when molten. Silicates of two or more bases are, as a rule, more fusible than those containing only one base. The more basic, within limits, is the slag, the more infusible and thickly fluid will it be. The temperature of the fusion zone must therefore be higher than is absolutely necessary for fusion purposes, and this results in the formation of a grey pig iron rich in silicon. Conversely, but again within limits, as the percentage of silica in the slag increases it becomes more and more fusible and thinly fluid in its character, and the pig iron produced passes through all the stages of mottled down to white, the temperature necessarily diminishing, and the fuel required becoming less and less in quantity. According to the degree of saturation of the silica, slags are divided into mono-, sesqui-, bi-, tri-, &c., silicates, the ratio between the silica and the bases present being respectively 1, $1\frac{1}{2}$, 2, 3, &c., equivalents of silica to 1 of base. Similarly mono-, bi-, tri-, &c., basic slags are also recognised. A mono-silicate may further be defined as that silicate in which the number of atoms of oxygen in the acid is equal to the number of atoms of oxygen in the bases present; in a bi-silicate the acid contains twice the number of atoms of oxygen, and a tri-silicate thrice that number. The author quotes largely from the writings of A. J. Rossi, Dürre, and others on this subject, and discusses the calculations of slags generally.

The Graphic Calculation of Slag Constituents.—Mr. A. J. Rossi* publishes a method for the graphic calculation of blast furnace slags. He illustrates his description diagrammatically. The method is similar in principle to other graphic methods.

The Disposal and Utilisation of Blast Furnace Slag.—The various means for the disposal and utilisation of blast furnace slag are described by Mr. W. Hawdon.† A small amount is used for road-metal, for making paving bricks and other slag castings, and some has been used for glass manufacture. The rest has either to be tipped on waste ground or carried to sea. In the latter case the slag has to be

* *Iron Age*, vol. xlvi. pp. 970-972; xlix. p. 342.

† *Proceedings of the Institution of Mechanical Engineers*, 1892, pp. 70-97, five plates.

in pieces of small size, or the barges are damaged when they are being filled. In some cases the American plan of running the slag into ladles or tanks on wheels and afterwards tipping it to form thin sheets, has been adopted; or a hollow cast iron core is placed in the slag ball so as to break it up as it contracts on cooling. Several forms of core have been used, but in most cases the slag breaks up into lumps which are still too large. Mr. E. Jones made the slag-bogies about 15 inches deep, and tipped the cooled slag on to knife-edged iron castings to break it up. Several mechanical conveyors have been designed, the earliest being that of Mr. T. Bell. Mr. C. Wood has described machines for making slag shingle and sand for cement, and for the manufacture of slag wool. The author has designed an endless chain slag machine, in which the slag is received in pans, which are fixed by lugs on their under-sides to an endless chain. The pans pass through a trough filled with water, which comes two-thirds of the way up to the edges of the pans, and water is also sprayed on to the surface of the molten slag. At Newport works there are eight machines. Each chain carries ninety pans, and is driven by a single cylinder engine at an average rate of 13 feet per minute. The machines together deal with 1000 tons of slag in twenty-four hours. As the pans turn over at the end of their travel, they discharge the slag into trucks made with side or end tip. Slag which follows the iron is run into cast iron troughs and broken up, whilst the main part is conveyed by a trough to the pans, which are filled to a depth of one or two inches. It there breaks up into pieces up to a few pounds in weight.

Slag has been extensively used at the Skinningrove Harbour works, which are described by Mr. W. Kidd.* Cleveland slag and slag cement were employed throughout the work, and the method of building the piers with these materials is fully described.† Good grey slag is most suitable for engineering purposes, but the black slag is very inferior material. The sulphur in the slag did not appear to interfere with the qualities of the cement, which gave excellent results under water. Slag balls, weighing three tons each, were tipped into the water direct from the furnaces, and, owing to their residuary heat, broke up into heavy rubble. There was some discussion as to the quality of slag as compared with Portland cement.

* Paper read before the Cleveland Institution of Engineers, Middlesbrough, April 4, 1892.

† *Iron and Coal Trades Review*, vol. xliv. pp. 546-547.

Slag Cement.—Slag cement* consists of granulated, dust-free, pulverised blast furnace slag and calcium hydrate. In 1890 in Germany ten manufactories produced 600,000 tons of this cement. The blast furnace slags suitable for its manufacture are basic slags disintegrating in the air, and always containing free lime. An analysis of a suitable slag from the Mathilde works at Harzburg gave the following results:—

SiO ₂ .	Al ₂ O ₃ + Fe ₂ O ₃ .	CaO.	MgO.
26·69	17·73	51·07	3·66

Strength of Slags and Slag Bricks.—The following are the results of a series of tests made at the Royal Testing Institution at Berlin, the crushing force being expressed in lbs. per square inch:†—

	Air Dried.	Set in Water.
Annealed slag (three varieties)	42,171 24,392 34,491	41,745 21,335 34,348
Blast furnace slag (Aplerbecker works)	25,957	24,321
Cupola slag from Krupp, Essen	41,745	40,251
Converter slag from Krupp	34,704	34,064
Compressed slag bricks	1,350	782
Slag bricks (two samples)	1,778 924	
Slag bricks (Harzburg)	2,347	1,991
Slag bricks (Giessen)	996	924
Slag bricks (Werden)	2,702	2,205
Slag bricks (Gladbach)	498	365
Slag bricks (Gelsenkirchen)	1,209	...
Slag bricks (Wetzlar)	2,133	2,062

IV.—FOUNDRY PRACTICE.

Charging Turnings into Cupolas.—J. Hansen‡ uses for this purpose an archimedian screw. This is hollow, and the borings being drawn into the furnace by the screw, are prevented from being blown out of the cupolas by two currents of air, one jet passing through the hollow screw, and an additional one passing into the furnace through a circular orifice surrounding the end of the screw.

* *Thonindustrie Zeitung*, 1892, No. 1.

† *Mittheilungen aus der Königlichen Technischen Versuchsanstalt zu Berlin*, 1891, p. 234.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 464.]

PRODUCTION OF MALLEABLE IRON.

The Theory of Puddling.—In discussing the theory of puddling, Mr. T. Turner * mentions as points which require special treatment: the most suitable composition of pig iron for puddling under given conditions; the effect of variation in composition on the yield and quality of the iron; the principles according to which the composition of the fettling should be varied to suit the given pig iron; the exact nature and sequence of the changes which take place in the puddling furnace; and the rules for varying the character of the pig iron for obtaining given qualities of iron.

The author has previously † discussed the removal of phosphorus, and he now treats of the removal of the silicon. The theory that the silicon is removed by the agency of ferric oxide has been widely accepted, but this substance is practically infusible, and a paper read by Sir William Siemens in 1868 before the British Association is quoted to show that the action is due to cinder, which consists of magnetic oxide with more or less of the tribasic silicate of iron. Ferrous silicate is readily reduced by carbon, and as readily reoxidised by the oxygen of the air, so that it acts as an important carrier of oxygen. It therefore has a considerable effect on the carbon in the iron, though perhaps it does not have any effect on the silicon present. For chemical action there must be contact between the bodies acted on, and accordingly the ferric oxide of the fettling cannot have any great direct effect till it passes into the cinder in solution. The really active material is the cinder, which contains magnetic oxide dissolved in ferrous silicate. The oxygen in the air also does not have much effect except in the melting-down stage and in producing waste of iron in the later stages. A moderate proportion of impurities will increase the yield of iron by reducing the metal from the cinder, but in the action of silicon on ferric oxide only ferrous silicate and oxide

* Paper read before the South Staffordshire Institute of Iron and Steel Works Managers, December 19, 1891.

† *Journal of the Iron and Steel Institute*, 1891, No. I. pp. 119-150.

may be produced with no reduction of the metal. It is for this reason that "best tap" and other materials rich in ferrous oxide are so largely used, and why steel scrap mixed with ferric oxide can be used. But the more impure the iron used, the more infusible must be the fettling as long as enough cinder is made to cover the iron. If too much silicon is present in the metal, it will take longer to work, and waste by atmospheric oxidation may more than counterbalance gain by the other means. Quick working is shown to be very advantageous by the experience of Mr. Kirk, who only makes a loss of $3\frac{1}{2}$ per cent. by making seven heats in the day instead of six, with a pig iron containing—

Silicon.	Sulphur.	Phosphorus.	Manganese.
1.0	0.14	1.23	0.70

The usual difference between the calculated weight and the iron obtained is about 20 per cent., and of this Mr. Kirk saves one-sixth or $3\frac{1}{2}$ per cent. of iron, which is about equivalent to 1 per cent. of silicon. The system of quick working of course demands low silicon contents such as used above, whilst the other method of saving iron is antagonistic, and demands high silicon and slow working. The first saves labour and fettling; the second allows of the use of a cheaper pig iron. In the South Staffordshire district, the waste of pig iron is generally 5 per cent., and often as high as 10 per cent. in making puddled bar. In many cases some of this loss might be prevented.

The Pietzka Puddling Furnace.—Mr. J. von Langer* describes the Pietzka puddling and heating furnace, which is being largely used at the Witkowitz works in Austria. This furnace has a double or reversible hearth mounted on a platform turning on a hydraulic ram. The pig iron is charged on one division of the hearth, which, when the metal has melted, is raised about 4 inches and turned round, so that a fresh charge can be placed on the other division whilst that already melted in the first division is being puddled. Gas fuel and regenerators are used. These furnaces have been in operation at the Witkowitz works for about twelve months, and will shortly replace all the ordinary puddling furnaces, and the Pietzka heating furnace has been adopted throughout the rolling-mills at these works. The average saving by the use of the furnace during the last half year has been 10s. per ton, the economy in iron being 2 to 3 per cent. The

* Paper read before the Cleveland Institution of Engineers, December 14, 1891, through *Industries*, vol. xi. p. 585.

new furnace requires eight hands, though this number may ultimately be reduced by economy in the firing. The old furnaces required only three hands, and the rate of wage was 7s. 10d. per ton. This rate has been reduced by one halfpenny per ton in the Pietzka furnaces, although the individual wages of the workmen have been increased by about one-third.

The Von Langer and Cooper puddling furnace is a modification of the Pietzka furnace. The chief modifications consist in placing the hydraulic lifting apparatus above instead of below the hearth; in dividing the space below the hearth into a serpentine course for the air; and in the form of the hearth.*

The Utilisation of Puddle and Reheating Cinder.—Cinder from puddling and reheating furnaces can now be utilised in the manufacture of paint, and a description of the process is given by Mr. A. Sahlin.† Plant for the manufacture was put up in Illinois about five years ago and abandoned, but that erected at Boonton, New Jersey, has been successful. Two samples of the cinder used have the following composition:—

	FeO.	Fe ₂ O ₃ .	MnO.	CaO.	Al ₂ O ₃ .	SiO ₂ .	P ₂ O ₅ .	S.
Puddle cinder	54.43	19.62	6.41	0.81	0.38	16.39	3.84	...
Heating cinder	71.29		0.21	...	7.78	20.06	0.27	trace

The latter is preferred. The cinder is crushed in a Blake crusher to pass a $\frac{3}{4}$ -inch wire screen, and is then conveyed to a 24-inch Cyclone pulveriser, into which it is fed automatically. The pulverised material is withdrawn by a continuously circulating air current which carries it through two settling chambers. The first chamber is 32 feet long by 3 feet wide by 11 feet high. Coarser material, which settles in the first part of this chamber, is withdrawn by screw conveyers and trap doors, and returned to the pulveriser. Some 40 per cent. of the finest dust settles in the larger chamber, and is cleared out by a revolving scraper. It is ground in a mill with linseed oil, and is used directly or with admixture of other colours. The material collected from the first chamber passing a 225-mesh sieve is mixed with sulphuric acid, and after the first action of the acid it is roasted, forming a light flaky red mass, which is again ground. Some difficulties were met in pulverising the material, but the Cyclone pulveriser was adopted as it gave

* *Engineering and Mining Journal*, vol. liii. p. 470.

† *Transactions of the American Institute of Mining Engineers*, Glen Summit meeting (advance proof).

a uniform product in spite of wear of the fan-blades. Chilled cast iron for these blades was the best, but was too brittle. Tool, chrome, and manganese steels were too costly; so Bessemer steel containing 0.3 to 0.4 per cent. of carbon is used, the cost of renewals being 8½d. per ton. The output of the plant is ten to twelve thousand pounds per day.

The Direct Reduction of Iron.—Professor J. von Ehrenwerth* continues his consideration of this question,† considering more especially the reduction of malleable iron in the Husgafvel‡ furnace. This furnace he describes and illustrates, giving the working results as obtained in Finland. The malleable blooms produced contained large quantities of slag—up to 15 per cent. Working in direct connection with an open-hearth, this furnace may, the author thinks, be of occasional advantage.

Professor Ehrenwerth also describes§ the Eames process as used by the Carbon Iron Company of Pittsburgh. In this process the ore is balled with coke and water, with or without lime or clay, and heated on the bed of a reverberating furnace. This process has held its own under the local conditions existing at Pittsburgh. Howe's *Metallurgy* is extensively quoted by the author in his description of this process.

In the Neville direct reduction|| process the furnace consists practically of a three-door reverberatory, at the end of which, opposite the fire-bridge, are two groups of three chambers, one above the other, through which the gases, after passing through the reverberatory furnace, escape on their way to the stacks. The charge, about 700 lbs. of ore, is charged into the top chambers. Thence it is dropped into the second chambers, from which the charge is afterwards allowed to fall into the lowest chamber, the position of the orifices alternating between the forward and the back end of the chambers. The charge is then pushed into the reverberatory furnace proper, where it is thoroughly stirred, being at the same time moved toward the fire-bridge, where the iron is balled, the balls being shingled under a hammer. At Rockaway, Ogden ore is being used, mixed with 20 per cent. of Cumberland coal as the reducing agent. The furnace is fired

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. pp. 456–459, with illustrations.

† *Journal of the Iron and Steel Institute*, 1891, No. II., p. 282.

‡ *Ibid.*, p. 188.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. pp. 545–549.

|| *Iron Age*, vol. xlix. p. 162.

with the same coal, and a series of jets of steam are introduced above the fire-bridge. The best time yet made in getting out a charge has been 1 hour 15 minutes, the charges following one another in succession as the upper chamber is cleared. It is claimed that the fuel consumption is about one ton of coal per ton of blooms. No exact data are yet available to show how great is the loss.

The Manufacture of Nickel-Iron Alloys.—Dr. H. Wedding* refers to the results of Riley's examination of the nickel-iron alloys. With regard to their mode of preparation, they may be made in blast furnaces from a mixture of oxide ores of iron and of nickel. The metal produced in this way is high in carbon, and is not suitable for conversion into malleable nickel-iron poor in carbon. On puddling such a carbon nickel-iron, oxides of nickel are formed, which are dissolved by the metal, and render it brittle to a much greater degree than would dissolved oxide of iron. To make a malleable nickel-iron alloy, metallic nickel must be added to the molten malleable iron. Nickel and iron do not form true alloys by themselves, but only mixtures, and to render these mixtures homogeneous some third metal, such as aluminium, must be added. Such experiments as have been from time to time recorded which relate to the alloys of nickel and iron having far from exhausted the subject, the German Society of Arts is about to undertake a further and more detailed examination of these alloys. Viewed from the results of Riley's experiments, it would appear that the alloys best fitted for general use are those with less than 0.3 per cent. of carbon, and the percentage of nickel should not exceed about 5. What percentages of these two elements in the alloys are actually the best in the whole series has not as yet been shown, and information is wanting as to the real mechanical properties of the best of the alloys, and how they should best be handled. This too will form the subject of the investigation referred to.

* *Verhandlungen des Vereins zur Beförderung des Gewerbefleißes*, 1892, pp. 52-65.

FORGE AND MILL MACHINERY.

Hot Charging and Hot Piling of Puddle Bars.—Improvements in furnaces and organisation in the works have left but little room for economy, according to Mr. R. R. Gubbins ;* but the initial heat in the puddled bar offers a certain field, as it requires at least three tons of fuel to heat twenty tons of cold puddled bars. Some years ago the author coiled the puddle bar hot, as it came from the rolls, round a block. The coil thus made was then flattened under the steam-hammer, returned to the furnace, reheated, and rolled off into finished iron. A circular block or former was preferably used, as the coil could then be rolled about, and by measuring the length of the bar coiled, sufficient accuracy in its weight was obtained. Several sized blocks for different work are required, so as to make the pile of the requisite size for subsequent rolling, but the steam-hammer may be used to a certain extent to draw down the pile to the right size. A pile to produce a bar of flat iron 2 inches by $\frac{1}{2}$ inch by 16 feet, weighs 64 lbs., and if made of puddled bar $3\frac{3}{4}$ by $\frac{7}{8}$ inches piled three high, will measure 22 inches in length, whilst a bar 3 inches broad will require a similar pile $33\frac{1}{2}$ inches long ; so the second block will have to be 4 inches larger than the first. The work of a bar-mill producing up to 3-inch squares and rounds and 6 by 1 inch flats can be dealt with by 14 formers. These are plain iron castings, which can be easily changed on the spindle. It was evident, however, that equally good results might be obtained by folding instead of coiling the bars. This may be done with great accuracy, so as to produce piles of any required weight, by nicking the bar nearly in two on opposite sides alternately, at regular distances apart, by means of nicking-rolls driven at a constant speed by the puddle bar-rolls. The difference of speeds, and the resulting length of the pile can be adjusted by means of change wheels. The nicked bar is folded and the piles collected on a trolley which is provided with a treadle arrangement and a peel, by which the furnace-charger and his attendant

* Paper read before the South Staffordshire Institute of Iron and Steel Works Managers, January 16, 1892 ; *Iron and Steel Trades Journal*, vol. 1. pp. 119-120.

can charge the hot piles into any part of the furnace without actually handling them. These rolls and the charging trolley have been previously described in this Journal.*

Besides the direct saving in fuel and labour, there is also a considerable saving in time, and increased yield through the absence of scale. When charging cold, six heats can be made in twelve hours, about seventy-five minutes being actually used in heating, whilst only fifteen minutes is required to bring the piles to the proper temperature if they are charged hot.

A considerable discussion ensued on the reading of this paper, and in reply the author stated that the different qualities of metal might be mixed in the piles either as alternate plates or otherwise, and defective pieces can readily be removed. The folding rolls are merely subsidiary and can be thrown out of work and the bars treated in the ordinary way at any time. The labour required is not greater, and the mill is not made hotter in this system.

A 4000-Ton Hydraulic Press.—M. Demenge† describes the 4000-ton press recently erected by the Compagnie des Forges de Chatillon-Commentry at the Saint Jacques Works, Montluçon. This is the most powerful press as yet erected in France. It is intended for forging large ingots to be used in the manufacture of armour-plate. The description is accompanied by a number of illustrations.

Electric Power Hammer.—An illustration is published in the *Iron Age*‡ of such a hammer intended for heavy forging. It is of ordinary construction, except that it is actuated by electricity instead of by steam.

The power cylinder is composed of a large number of superimposed solenoids of short length and large diameter surrounding an iron plunger, which is connected to a block or hammer below the rod. The sectional coils are connected to a corresponding number of stationary and well-insulated segments, and upon these segments bear three brushes or contact-plates, so that by placing the three contact-plates and keeping them stationary upon any part of the sectional commutator, the current pulsations will take place between the respective contact-blocks, and will reciprocate the plunger within the field created

* 1891, No. I. p. 381, and 1890, No. II. p. 771.

† *Génie Civil*, vol. xx. pp. 65-71.

‡ Vol. xlviii. p. 1115, one illustration.

by the coils, so that by simply moving a handle the contact-blocks will be displaced upon the sectional commutator, thus displacing the magnetic field of the coils. By so doing they will be made to play within a certain region, and can also be made to strike a light or heavy blow, according to the distance between the hammer and the work. The handle further regulates the power of the blow by placing more or less resistance in the return circuit.

The Construction of Rolling-Mills.—In an exhaustive paper, illustrated by eleven drawings, Professor C. A. Ångström * discusses the design of rolls for rolling-mills, beginning with the ancient rolls described by Svedenborg in 1734, in his *Regnum subterraneum sive minerale de ferro*, and dealing with the modern blooming-mills of the two-high type, and with the three-high rolls for the further reduction of the blooms to rails and shapes. The mathematical theory of the subject is fully entered into, and the best dimensions for the mills for various purposes are given.

In his address as President of the American Society of Mechanical Engineers at the New York meeting, Mr. R. W. Hunt † gave a historical sketch of the rise and progress of the rolling-mill in the United States. The first rolling-mill was that of the Mount Savage works, Allegheny county, Maryland, erected in 1843 and started in the following year. No 30-foot rails were made to order until 1859, though some had been made four or five years before. One of the earlier mills which has survived the lapse of time is that of the Cambria Ironworks, Johnstown, Pennsylvania. This was originally built in 1853. Up to 1857 all the United States mills used non-reversing two-high trains. The three-high mill was started at the Cambria works on July 29, 1857, when six rail-piles were charged and heated, and three rolled into rails. In 1866 all the rolling-mills of the United States had adopted the Fritz three-high mill. The first commercial rolling of steel rails took place at the Cambria works in August 1867, the order for them having been given by the Pennsylvania Railway Company. These were rolled in a three-high 21-inch train. Mr. Hunt then proceeds to refer to the Fritz blooming-mill, and compares blooming with hammering. In 1868 the Freedom Iron Company, of Lewistown, Pennsylvania, erected a works provided

* *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xxxix. pp. 353-422.

† *Iron Age*, vol. xlviii. pp. 880-884.

with British machinery, including a reversing plate-mill driven by a reversing Ramsbottom engine. The question of straightening and cambering and the use of automatic tables is next considered, and a number of the more important trains are referred to in detail. Cold-rolling, plate-rolling, and the rolling of wire rods, tires, and of fluid metal is also discussed.

Modern American Rolling-Mills.—The first rails were rolled in the new Edgar-Thomson mill in 1888.* The blooms on their way from the blooming-mill to the rail-mill pass through reheating furnaces. The rail train is divided into three sets, the first two with three-high rolls, the last with but two, all of 24-inch pitch, each set being driven by its own engine, and provided with automatic tables. In the first or roughing rolls five passes are made. The bloom is then carried by driven rollers to the second or intermediate train, in which it receives five more passes, and is then carried to and through the finishing pass in the two-high set. These trains are placed in échelon and far enough apart to permit three 30-foot rails to be rolled. The mill is a very simple one, and has many mechanical arrangements which make roll-changing the work of but a few minutes, while every part of each set of rolls is easy of access. After the rails leave the cambering machine, they are carried down the hot bed by power, and automatically distributed to the cold straightening presses. This arrangement is simple, substantial, and inexpensive in operation. The mill has made 781 tons of rails in twelve hours, 1558 tons in twenty-four hours, and 33,181 tons in one month.

The old blooming-mill has been replaced by a 40-inch mill which rolls ingots weighing 4500 lbs. into 7-inch blooms in nine passes. This mill has an auxiliary feed-table which is placed in front of the table of the train. An ingot is placed upon this table while the one preceding it is being rolled. As soon as it leaves the last pass, the ingot waiting on the auxiliary table is fed to the train table by simply raising the former, thus saving the time which is otherwise lost in getting the next ingot into place on the feed-table. This saving is stated to be as much as 15 per cent. A number of other modifications have also been introduced, among which is a simple device for causing one waggon to pass another on the same track. It consists in placing at the point where the two waggons meet a track section, the two legs of which form an obtuse angle, and which rests on

* *Iron Age*, vol. xlviii. pp. 882-884.

trunnions at a sufficient height above the stationary track to allow one waggon to pass clear under it. One set of legs of this false track rests upon the stationary track at the upper portion of the incline, thus causing the descending waggon to mount it, while the ascending waggon is passing under it on the stationary incline track. As soon as the descending waggon has got beyond the trunnions, its weight tips the false track until the other legs rest upon the lower part of the incline track, the tipping at the same time clearing the way for the ascending waggon. The waggon once passed, the balanced track resumes its original position.

The South Chicago rail-mill is divided into two sections, each having two sets of rolls in three-high housings, each section being driven by its own engine, and provided with automatic tables both before and behind the rolls. These trains stand in échelon with the blooming-mill, which is a 40-inch three-high train. The rail-mill rolls are of 27-inch pitch.

In this mill the practice is to cast the ingots in the ordinary upright position, and then to charge them into gas-fired soaking-pit furnaces of the Forsyth-Hainsworth type. After the ingot is reduced in the blooming-mill it is carried by power rollers towards the first rail train, and through a shear by which the end which was the top of the ingot is cut off and the long bloom sheared in two, each half making two or three rails, according to weight of intended section. The first half at once passes through the rail-roughing rolls, the second one being held for a few seconds, or until the first has made three passes, when it is also sent forward. If from any reason the bloom when sheared should have become too cold to be safely and successfully finished, a power overhead-traveller is provided to carry it at a right angle into a wing at the side of the mill, in which heating furnaces are placed, with a Wellman charging and drawing crane in front of them. When sufficiently heated the same crane conveys the steel back to the table-rollers.

By this arrangement cold cobbles or other rail blooms can be heated and delivered to the rolls. In the roughing rolls the bloom receives five passes in three-high rolls. It is then passed to the second roughing tables, and is given three passes in three-high rolls. The partially formed section is elevated to the rear tables of two-high rolls, and making one pass through them, reaches a dummy table in front, from which it slides down on to driven rollers, and is by them carried back to the three-high set of rolls, which are in line with the first roughing

rolls and driven by the same engine. In these it receives four passes, making in all thirteen rail-mill passes. It is now a finished section, long enough to cut into three 30-foot rails. This is done at one operation by four saws. After passing through the cambering machine the rails are carried by power down the hot beds. When sufficiently cool they are taken to the cold straightening presses, and are unloaded on to the beds by an automatic arrangement of arms and levers which receive their power from steam taken from the locomotive boiler.

The Shenandoah rolling-mill in Virginia is intended for the manufacture of muck and bar iron. The plant comprises a puddling furnace building, containing 12 double-puddling furnaces, each being equipped overhead with a return tubular boiler, 54 inches in diameter and 18 feet long, pierced by eighteen flues 6 inches in diameter. The furnaces are arranged for both natural and forced draft. The squeezer is designed for the delivery of an 8-inch bloom, being operated by an independent engine 20 by 20 inches.

The muck-mill is a two-stand three-high 22-inch train, driven by a 30 by 48-inch engine. The muck shear is driven independently by a 9 by 12-inch engine. An overhead travelling-crane is provided over the roll train to facilitate the changing of rolls, &c.

The bar-mill department consists of an 18-inch and a 10-inch three-high train, the former containing two stands and the latter four stands of rolls. Each mill is driven by an independent engine, that attached to the 18-inch mill being 30 by 48 inches, and that connected to the 10-inch mill being 20 by 24 inches. Cooling beds are provided for each mill, and the shears are driven by independent engines. The shear-engine for the 18-inch mill also drives the underground saw used in connection with this mill. To simplify the handling of rolls a travelling crane is provided over the bar-mills.*

An illustration is published † of a taper-rolling machine which will roll $1\frac{1}{2}$ -inch metal to any length of taper, and to an extreme width of $5\frac{1}{2}$ inches. On the front of the machine is a sliding table for squeezing and straightening the blank. This table is operated by a cam projection formed on the side of the gear driving the upper roll through a pinion on the shaft carrying the driving pulley. The stroke of this table is adjustable. The lower roll of the machine is driven by gear from the upper one. The faces of the rolls are so formed and so placed in relation to each other as to give the ends of the blank the taper desired. This action

* *Iron Age*, vol. xlviii. p. 1072, with plan of mill.

† *Ibid.*, vol. xlviii. p. 921.

of the rolls spreads the ends and increases the width of the plate; the excess being removed by the sliding table moving transversely in front of the rolls as described above. The machine performs the operations of tapering, squeezing, and straightening at one heat.

In 1882 Mr. W. Garrett patented and built a wire rod mill arranged to take a billet of a large enough section to permit its being rolled direct from the ingot without any reheating. He decided upon four inches square as being that size. To accomplish this he went beyond the Belgian mill by introducing three separate trains of rolls, placed in échelon, and driven at progressively increasing speeds. Hence the billet rolls could run at all speeds suitable for the workmen to handle the billets without interfering with the speed of the finishing trains. This arrangement not only permitted the use of the larger billet, but made it possible to have several distinct pieces in the rolls at the same time. The present practice is four pieces, and sometimes five rods will be reeled off simultaneously.*

In the Gautier rolling-mill the billets are heated in two open-hearth furnaces. The 10-inch train is driven from a tandem compound Southwark engine by belts. The mill consists of one 18-inch roughing train, and one 10-inch train with seven sets of rolls, and an inclined disappearing floor. The bars are delivered to a Baldwin stretcher; from this they pass to a rotary cooling rack and straightener, and thence to the cooling beds. Between the shipping department at the end of the mill and the mill itself is a depressed line of rails, bringing the waggon to the level of the mill. This track is crossed by four drawbridges, so counterbalanced that they can easily be moved by hand. For heating the mill the Sturtevant system has been adopted.†

The West Superior rolling-mill contains two trains of rolls. One train, driven by a reversing engine, consists of separate stands of roughing and finishing plate rolls, 30 by 90 inches. The other is a three-high train of 20-inch rolls, intended for a varied product, embracing I-beams up to 12 inches, channels up to 12 inches, angles and tees of all sizes, flats up to 8 inches by $1\frac{1}{2}$ inch, and rounds and squares up to 4 inches. To render this train of rolls as automatic as possible, feed-tables are used to handle the ingots and slabs, and power-tables carry away the completed plates to the shearing shed. The structural mill is a 20-inch train with housings of extra strength, having both top and bottom screws. When rolling the larger sizes of beams and channels steel roughers will be used, the ingots for such work having

* *Iron Age*, vol. xlviii. p. 883.

† *Ibid.*, vol. xlviii. p. 1062.

been previously bloomed down on the roughers of the plate-mill. Owing to the varied product of this train, an automatic feed could not be arranged, but an overhead mechanism has been provided, which supports and largely directs the movements of the hooks on either side of the rolls. The hot beds are arranged like those of a steel rail-mill, with driven rolls and power traverse for the more expeditious handling of the product.*

The new plate train of the Wellman Iron Company of Thurlow, Pennsylvania, was started in December 1891. It has rolls 132 inches in width, is driven by a 40 by 60 Corliass engine, and is served by a 30-ton Morgan electric crane.†

A skelp train at Wheeling, United States, with three stands of three-high 21-inch rolls, is being erected at the Riverside Ironworks. It is to be driven by a 36 by 48-inch engine. The train is intended to roll skelp up to 22 inches in width, the works making a speciality of slitting skelp to various sizes for use in the manufacture of steel pipes. The train is fed by two heating furnaces having four producers. Their capacity is estimated at three tons per heat and seven heats per day. They are to be served by a crane 26 feet in height with 32-foot jib.‡

The new billet-mill of the Cambria Ironworks, Johnstown, Pennsylvania, is three-high with 26-inch rolls. It is in line with the blooming-mill. The heating furnaces are sufficiently large to store two heats if required. The engine has 36-inch and 75-inch cylinders, with a 66-inch stroke and a 90-ton fly-wheel.§

The agreements governing the rate of wages paid in the blooming department of the Columbia Steelworks, Uniontown, Pennsylvania, are printed in full in the *Iron Age*.||

Rolling-Mill Engines.—Several detail drawings of a set of rolling-mill engines made by a Glasgow firm are given in *Engineering*.¶ A general view of the engines is shown with detail views of the cylinders and link motion. Piston valves are used. The links are operated by means of a reversing engine, which is simple yet efficient and quick in action. The sole plate is cast in one piece and is of strong design.

The engines for a 40-inch cogging-mill at Newburn are illustrated in the *Engineer*.** The cylinders are 46 inches in diameter with 5-foot

* *Iron Age*, vol. xlix. p. 197.

† *Ibid.*, vol. xlviii. p. 1127.

‡ Vol. xlviii. p. 684.

** Vol. lxxii. pp. 438-440.

† *Ibid.*, vol. xlviii. p. 1127.

§ *Ibid.*, vol. xlviii. p. 1062.

¶ Vol. lii. pp. 656-657, 660.

stroke. Piston valves 19 inches in diameter are used. The pistons are 13 inches thick, and the piston-rod 8 inches in diameter. The crank-shaft is $17\frac{1}{2}$ inches in diameter, $26\frac{1}{2}$ inches long in the journals, and 22 inches in diameter in the body. The second motion shaft is $20\frac{1}{2}$ inches in diameter in the journal, and is driven by helical gearing $4\frac{1}{2}$ and $11\frac{1}{2}$ feet in diameter on the pitch line, 24 inches broad, with teeth of $8\frac{1}{2}$ inches pitch.

Steam Economy in Rolling-Mill Engine Practice.—The necessity of greater economy with regard to steam in rolling-mill engine practice is urged by Mr. D. Ashworth.* As a general rule, not so much regard is paid to fuel economy by having the best type of engines as in other places, such as cotton or flour mills, where quick cut-off valves and a good design enable the greatest possible amount of work to be got out of the steam. The requirements for rolling-mill engines are, first, massive proportions to receive all shocks and intermittent strains; second, liberal ports for steam and exhaust, free and uninterrupted flow of steam from main pipe, an entire absence of throttling or wire drawing; third, clearance reduced to a minimum; fourth, quick-acting valve movements with least number of parts, cutting off under varying loads from $\frac{1}{4}$ to $\frac{3}{4}$ stroke. High steam pressures should be used, and also condensing engines. The engines should be built more compactly and the drivers should be selected men.

Manipulating Plates in the Rolling-Mill.—An apparatus for the manipulation of iron and steel plates during the process of finishing is described by Mr. G. Curtis.† Its special features are the small space required, the economy in labour, the distribution of the plates, and the facilities and time allowed for their cooling. The apparatus is shown applied to a three-high 32 by 19 by 120 inch Lauth mill, served by four heating furnaces, with hydraulic charging and drawing cranes. The plate as it leaves the rolls is caught by automatic tongs, supported by an overhead carriage moved by a hydraulic cylinder. These tongs are worked by a boy who can readily raise or lower them and cause them to draw the plate on to the straightening table. This table is some 63 feet in length, and consists of heavy bars 12

* *Transactions of the American Society of Mechanical Engineers* (advance proof).

† *Transactions of the American Institute of Mining Engineers*, Glen Summit meeting (advance proof).

inches apart, and fixed at one end only to allow for expansion. The plate is then transferred laterally to the cooling bed by means of blocks on endless chains, spaced apart sufficiently to take the widest plates rolled. There are two chains to each bed, of which there are three, which can be worked together or separately by suitable clutch arrangements on the shafts which drive the chains. The straightening table and cooling beds will accommodate fifteen 20-foot plates, and the cooling can be accelerated by water placed under the table and beds, and by a gentle blast of air. The chains are worked so as to move the plates forward step by step, and then to deliver them on to carriages running on V-rails. By lowering a set of rollers on these carriages the men in charge can set the plate exactly up to gauge, and then the plate is clamped and run to a slitting shears by a hydraulic cylinder which moves the carriage. It is then brought back, the plate turned over by hydraulic power, and the process repeated for trimming the other side, after which it is taken to guillotine shears to trim the ends. As power and gravity are used to manipulate the plates, only two men are required, and they can handle plates up to three tons in weight.

PRODUCTION OF STEEL.

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I.—THE CARBURISATION OF MALLEABLE IRON.

Crucible Steel in Russia.—S. Kern * discusses the manufacture of crucible steel in Russia. At the Poutiloff Ironworks, St. Petersburg, there was erected in 1889 a Siemens gas-furnace with three compartments, each for ten crucibles, and a muffle furnace to heat sixty crucibles. The charge for each crucible comprises 62 lbs. of raw material. The following are the materials used :—

	Graphite.	Comb. Carbon.	Mn.	P.	Si.	S.
1.	1·380	3·800	1·040	0·019	0·728	0·025
2.	...	0·020	0·070	0·014	0·003	0·014
3.	1·200		...	1·020	...	0·015
4.	0·370		...	0·046	0·110	...
5.	1·050		...	0·024	...	0·015
6.	0·310		...	0·046	...	0·150
7.	0·850		...	0·020	...	0·015
8.	0·255		...	0·030	...	0·150
9.	0·450		0·985	0·062	...	0·027
10.	0·090		0·440	0·040	...	0·022
11.	0·958		...	0·042	...	0·068
12.	1·082		...	0·075	...	0·071
13.	4·020		74·710	0·077	...	0·880
14.	2·930		14·940	...	10·420	...
15.	9·030		0·700	0·080	0·620	0·030
	(Cr. 49·25, Al. 2·28)					

1. Swedish cast iron; 2. Swedish iron, J. M.; 3, 5, 7. blister steel, W. F.; 4, 6, 8. Russian puddled steel; 9. acid open-hearth steel; 10. basic open-hearth metal; 11 and 12. old crucible steel; 12. mostly files; 13. ferro-manganese; 14. ferro-silicon; and 15. ferro-chrome, from Bocan, France.

* *Chemical News*, vol. lxx. pp. 133, 158, 170.

Several samples of the ferro-chromium contain 60 per cent. of chromium, and one 11.03 per cent. of carbon.

Each crucible used weighs 50 to 55 lbs., and is composed of—

	Per Cent.
Fireclay	43.5
Burnt clay	36.5
Old crucibles	11.0
Graphite	9.0

The raw fireclay contains—

SiO ₂ .	Al ₂ O ₃ .	MgO.	CaO.	Fe ₂ O ₃ .	Alkalies.
50.00	47.00	0.46	0.52	2.05	0.71

This clay rarely contains pyrites. The crucibles are dried at a temperature of 40°–45° C. for six or eight weeks. The cost of a crucible with its cover is 1½ rouble.

The gas-furnace makes 4 to 4½ heats a day. The metal is cast into about 70-lb. ingots, 4 inches square. Three grades of steel are made: For planing tools, 1.20 carbon; for drills, 1.00 carbon; and for cutting and stamping tools, 0.85 carbon; the other constituents being—

Mn.	Si.	S.	P.
0.18	0.20	0.02	0.03

When casting small articles ferro-aluminium is used, but always in admixture with ferro-silicon, about 0.6 lb. of the mixture to a melt of 62 lbs. The ferro-aluminium is prepared by melting 70 per cent. of grey pig iron with 30 per cent. of ferro-silicon, containing 10 per cent. of silicon, and then pouring this when molten on to 12 lbs. of aluminium, stirring, and then pouring into another crucible. Details as to cost are also given.

Steel-Making in the United States before 1810.—A short and interesting account of the history of steel manufacture in the United States is given by Mr. W. F. Durfee.* In 1728, S. Higley and J. Dewey were granted a patent, which, however, appears to have fallen through. Privilege was then, in 1740, granted to Messrs. Fitch, Walker, and Wylls, who made half a ton of steel before 1744. It appears from returns made in 1750 by the Colonial governors that Massachusetts, Connecticut, and New Jersey each possessed one furnace, and that there were two furnaces in Philadelphia. In 1777, Rhode Island gave £60 per ton for good "German" steel made within the State, and ten years later it was cheaper than the imported article in Massa-

* *Popular Science Monthly*, vol. xxxix. pp. 729-749.

chusetts. By 1791 half the steel consumed in the States was home-made, and new furnaces were building. Swank gives the production in 1810 as 917 tons of steel, of which Pennsylvania produced 531 tons in five furnaces.

All steel produced in America prior to 1810 was made either by the "German method" or by cementation. The former process was conducted on a hearth similar to a bloomary fire, either ore or pig iron being used; but the materials then available were not suitable, so attention was directed to the cementation process at an early date.

Crucibles for Steel-Melting.—Mr. C. K. Everitt in a paper before the Sheffield Technical School Metallurgical Society described the various forms of crucibles used for steel-melting, and discussed their merits. A pot of his own invention is made with a basic lining.

II.—THE OPEN-HEARTH PROCESS.

Open-Hearth Steel Castings.—Mr. J. A. Herrick * states that to the best of his knowledge the first open-hearth castings were made in the United States in 1872. They were satisfactory as castings, but not as regards cost of production. The author describes the arrangement of an open-hearth foundry plant, consisting of a 10-ton furnace, cranes, drying ovens, cupola, foundry proper, chipping-shop, and other appliances and shops.

The Open-Hearth Process.—R. M. Daelen † discusses the various papers relating to this subject which have lately appeared. With regard to the furnace itself, the size of the ports for the gas and the air is of the greatest importance; they should neither be too large nor too small, each of which alternatives has its disadvantages. The regenerator chambers should not be too tightly packed, and the size of the flues and the stack should be carefully regulated. The gas and air ports should not be placed too close to the hearth. Horizontal regenerator chambers should be avoided. They are difficult to clean out, and only the upper portion is in active use.

The rapidity of the open-hearth process has been greatly increased in recent years, and the modern method of a mixed Bessemer and

* *Iron Age*, vol. xlix. p. 202, with plan of works.

† *Stahl und Eisen*, vol. xii. pp. 11-17, with a sheet of illustrations.

open-hearth process—the duplex system—appears likely to produce a great change in the ordinary open-hearth process, the cost of this double system being much less than if the process was commenced and completed in the open-hearth alone. The wages are less, the fuel burnt is reduced enormously, the cost of maintenance is diminished, and the output largely increased.

The author refers to the paper of Hibbard,* and to that of Pourcel,† on the ore process. The size of the open-hearth is being rapidly increased. The question of the furnace-lining is also considered. The following is an analysis of a chrome iron ore which may be considered as representing a neutral lining, showing, as it does, an equal resistance to both acid and basic slags. Such an ore should never contain more than 5 per cent. of silica nor less than 45 per cent. of chromic oxide.

Cr ₂ O ₃ .	Al ₂ O ₃ .	FeO.	MgO.	SiO ₂ .
44·10	6·72	22·42	23·14	3·16

Dalzell Iron and Steel Works.—An illustrated series of articles on the Dalzell Iron and Steel Works, Motherwell, have recently appeared.‡ In the iron department there are thirteen puddling furnaces, of which two are ball-furnaces, a 5-ton and a 3-ton steam-hammer, a forge-mill with three pairs of 18-inch rolls, an 18-inch merchant-mill, and a 10-inch guide-mill. There are also two sets of bloom-shears, and five heating furnaces with boilers above.

In the steel department, the Siemens gas-producers number twenty-eight stacks, each with four chambers. There are sixteen open-hearth furnaces, of which three are 12-ton, three 16-ton, eight 18-ton, and two 25-ton. The capacity is 10,000 tons of finished material per month. These furnaces are placed in two lines at right angles, and in the corner are four heating furnaces. For hammer-power there are two 12-ton hammers, and close by are nine Siemens heating-furnaces. The mills are three in number, each with its own engine, and are placed in line, so that any engine can drive the adjacent mill. The Jardine screw gear is applied to these mills, and they are also provided with live rollers. Details of the sizes of the rolls and of the engines are given. An annealing furnace for armour-plate can take plates up to 30 by 10 feet. One 50 and one 54-ton testing-machine are placed in the testing-house. Cranes and other appliances are also mentioned. The works are lighted throughout by electricity.

* *Journal of the Iron and Steel Institute*, 1891, No. II. p. 268.

† *Ibid.*, p. 264.

‡ *Industries*, vol. xii. pp. 436, 464, 488.

New American Open-Hearth Steelworks.—An open-hearth plant is in course of erection at Aliquippa, a place about twenty-two miles from Pittsburgh. A 15-ton open-hearth is being built, as well as a 36-pot crucible furnace, and space has been left for another open-hearth of similar size. A 26-inch train of rolls and a 6-ton hammer, with the necessary engines and other plant, are also being constructed. The rolling-mill engine is to be a Corliss engine of new construction.*

The West Superior Steelworks, Wisconsin, is the first steelworks of the Lake Superior region. It is intended mainly for the manufacture of plates, and is stated to be the first Bessemer steelworks erected in the United States specially for this purpose. The steel plant proper consists of two 6-ton converters arranged with a large clear space around them. The cupolas in the rear are sufficiently far from the converter to permit a crane to swing, and this is used for charging metal into the converters, and handling the converter bottoms. The trunnions of the converters are set in friction or roller bearings. These are controlled by screws, and are capable of easy adjustment. The converters are rotated by an 8-cylinder hydraulic engine placed beneath the floor and geared to the trunnion by a double Dodge chain. The casting-pit is of large radius, and hydraulic cranes are employed throughout. The drying-ovens for the bottoms are in the converter-shop, in line with the space between the converters and the cupolas. The blast for the converters is supplied by two vertical blowing-engines. The rolling-mills contain two trains of rolls.†

This steel plant is the outcome of a foundry which was started in the winter of 1889-90. A machine-shop was then added, and now blast furnaces will probably be also added. The works possess a large frontage to the Lake, and great care has been taken in their erection to employ labour-saving devices.

III.—THE BESSEMER PROCESS.

The Manufacture of Steel in Small Converters.—A method devised by Walrand and Legénisiel for the manufacture of steel in small quantities, up to half a ton, in small converters, consists in the addition of ferro-silicon to the charge after a preliminary blow. The apparatus already installed in Paris is designed for charges of 550 lbs., the vessel being a miniature Bessemer converter 52 inches high and

Iron Age, vol. xlix. p. 201.

† *Ibid.*, vol. xlix. p. 196.

28 inches external diameter, with the blast admitted from below. After charging the metal melted in a cupola, the air-pressure is turned on at 1·7 to 2·2 lbs., diminishing to 0·88 lb. near the end of the first period, which lasts from eight to even twelve minutes. Five per cent. of ferro-silicon containing 10 per cent. of silicon are then added in a molten state and the blast again turned on. The additional silicon by its combustion soon heats the metal to a point when it can be poured, the temperature before the addition being much too low for casting. The second blow lasts from 1 to 1½ minutes, and the metal is then cast. The castings appear to be good and sharp and free from blowholes, the metal being quiet in the moulds. When forged, the steel appears to be fibrous. Six charges were made in 3½ hours, and the linings last eight to nine operations. Analyses of the pig iron used and the steel made are as follows:—

Carbon	4·20	0·65	0·42	0·18	1·16
Silicon	1·23	0·25	0·27	0·04	0·02
Manganese	0·23	0·70	0·50	0·23	0·18
Sulphur	0·02	0·02			
Phosphorus	0·03	0·03			

The first two castings were somewhat hard, the last two welded well. The soft metal showed tensile strengths of 24 to 31 tons per square inch, with elongations of from 8 to 15 per cent.*

Difficulties were at first experienced with the Walrand process, but they have now been overcome by M. Walrand, and the process is now in regular work. O. Vogel† considers the question as to what the improvement is which has led to this change. With regard to the composition of the pig iron treated by this process the following are analyses:—

	C.	Si.	Mn.	P.	S.
I.	3·80	2·0-2·5	0·7-0·8	0·06	0·04
II.	4·20	1·23	0·25	0·03	0·02

The latter being a charcoal iron. Steel made by this process contained—

C.	Si.	Mn.	P.	S.
0·120	0·040	0·350	0·035	0·023

The great improvement in the process has been thought to be the use of regenerator chambers and hot-blast. It must be something which increases the temperature of the metal. The author believes it to be the addition of ferro-silicon, ferro-aluminium, or even of

* *L'Ancre* (de St. Dizier).

† *Stahl und Eisen*, vol. xii. pp. 17-19.

aluminium itself. Whatever it may be that is now employed, it has rendered the Bessemer process on a small scale a practical success.

The Basic Process in Sweden.—The iron ores of Sweden have been noted from time immemorial for their freedom from phosphorus. As the purest varieties, those of Dannemora, with only 0·002 or 0·003 of phosphorus, and those of Persberg, in Vermland, have a high reputation. Apart from these extremely pure ores, the great majority of the remainder, other than bog or lake ores, contain only from 0·005 to 0·05. In a few cases, ores with as much as 2 per cent. of phosphorus have been met with, due apparently, in the majority of cases, to the presence of included apatite. To so great an extent is this the case with the ores of the Grängesberg mines, that it was at one time thought possible to extract the phosphorus by wet methods. A portion of the Kopparberg ores, and those of Kirunavara, and some of the Gellivara deposits are also rich in phosphorus.* Ores with over 0·1 per cent. of phosphorus were formerly used for castings, or were used in admixture with purer ores. Now the basic process is being introduced into Sweden. At the Domnarfret works there were formerly three acid 5-ton converters. Now there are five converters, two of which are acid-lined, and the other three basic-lined, taking 6-ton charges of pig iron, which is brought direct from the four blast furnaces which the works possess. This pig iron has the following percentage composition—

Mn.	Si.	S.	P.	C.
0·50-0·75	0·50-0·75	0·02	2·5-3·0	3·5-4·0

This basic plant was started in October 1891.

Details have been published † relating to the construction of the converter ladle, &c., employed.

In addition to the iron ores of Grängesberg, which have hitherto been but little used, it will now be possible to employ also the phosphoric ores from Lapland.‡

Machine for Converter Bottoms.—R. M. Daelen§ describes a machine for forming converter bottoms. In the case of the basic bottom, hand-stamping is a matter of some difficulty, owing to the tar

* *Stahl und Eisen*, vol. xii. pp. 8-11, two illustrations.

† *Jernkontorets Annaler*, vol. xlv. p. 231.

‡ *Berg- und Hüttenmännische Zeitung*, vol. li. p. 7.

§ *Stahl und Eisen*, vol. xii. p. 113, two illustrations.

fumes arising from the hot bottom. The machine described resembles a steam-hammer, the stamp-head being placed directly below a steam or compressed air cylinder, and connected to the piston. One workman controls it, and in one shift he can make two or three of the bottoms, each of which will stand twenty heats.

The Edgar-Thomson Steelworks.—These well-known works, which are situated at Bessemer, Pennsylvania, are about to undergo considerable alteration, as far as the Bessemer shop is concerned. It has been decided to adopt the system of casting the ingots on waggons. The pits will be abandoned.*

An American Steelworks Record.—The October record of the South Chicago mill of the Illinois Steel Company is stated to have surpassed anything yet accomplished.† It was as follows :—

	Tons.
Ingots, 8-hour turn	674
Ingots, 12-hour turn	1,006
Ingots, 24-hour turn	1,914
One week	10,045
One month	42,638
Greatest number of heats in 12-hour turn, 91.	

The following is the record of the rail-mill for October 1891 :—

	Tons.
Best 12-hour turn	845
Best 24-hour turn	1,571
One week	8,152
One month	34,381
Night turn, October 5, rolled 2920 rails, 65 lbs. to the yard.	
October 27, day turn rolled 2945 rails, 60 lbs. to the yard.	
Total number of rails rolled during the month	121,697

The best achievements of the Edgar-Thomson works are reported to be as follows :—

	Tons.
Ingots, 12 hours	957
Ingots, 24 hours	1,734
Ingots for month	40,249
Rails, 12 hours	781
Rails, 24 hours	1,558
Rails for week	8,015
Rails for month	33,181

* *Iron Age*, vol. xlviii. p. 1114.

† *Ibid.*, vol. xlviii. p. 830.

Bessemer Plant at the Cambria Steelworks.—The new Bessemer plant of the Cambria Iron Company of Johnstown, United States, is to consist of two 11½-ton converters, the spiegeleisen cupolas being placed above the platform between the converters. The old plant, consisting of two similar-sized converters, which is being dismantled, produces 1100 tons of ingots per day, the best day's output having reached 1339 tons. The ladle-driers, ten in number, are arranged in two groups of three each, and one of four. A traversing table between each two rows takes the ladle to the drier. These are coke-fired with a large orifice, against which the tilted ladle is pushed, and which it closes. The plant will be served by a travelling crane. The open-hearth plant contains Pernot furnaces, which are stated to be doing good work. One of the open-hearths is arranged for the Adams-Blair process.*

The Duquesne Steelworks, United States.—At these works, which now belong to Carnegie Brothers & Co., there are two 7-ton converters, three open-top 10-foot cupolas, and one 8-foot cupola. The spiegel cupola taps into a ladle which is transferred to a crane serving both converters. For changing ladles a crane transfers to an adjoining pit, where trunnion rests are provided for the old and the new ladle. There are three vertical blowing-engines, 31 by 46 by 48 inch stroke, placed in an adjoining building. The ingots, which weigh from 3500 to 4000 lbs., are transferred to fourteen soaking-pits.

The blooming-mill is a 28-inch train driven by a pair of 28 by 48-inch reversing horizontal engines. At a distance of 75 feet from the centre line of the blooming rolls lies the three-high 26-inch roughing train, equipped with Treat tables, which while they lift the bloom at the same time swing laterally to bring it to the next pass. This train, in which the bloom makes five passes, is driven by a 46 by 60 horizontal engine. From this roughing train the billet is conveyed by driven rollers to the intermediate train. While passing along this conveyer the billet is turned, which ensures square rolling of the billets. Between the blooming-mill and the roughing train is placed a power-driven horizontal shear, the bloom ends being delivered out of the mill laterally by a special conveyer. On the conveyer from the roughing rolls to the intermediate trains is a switch, by which the billet from the roughing train may either be sent through one pass in the intermediate train, which rolls it into a 4-inch billet, or be

* *Iron Age*, vol. xlviii. p. 1062.

diverted to the first of six passes by which it is rolled into $1\frac{1}{2}$ -inch billets.*

The Maryland Steelworks.—The Maryland Steelworks at Sparrows Point, Maryland, possess Bessemer plant which is of novel design. The pit is done away with, the ingots being cast on trucks drawn along under the ladle. This method has worked well even under the most adverse conditions. It has been manageable even when it was found necessary to pour the steel over the ladle instead of tapping it, and when from accidental causes the flow of steel from the ladle has been extremely rapid.†

A Chinese Steelworks.—The plant was recently forwarded to China for a Bessemer steelworks. It includes two 5-ton converters, with the necessary cupolas, blowing engines, cranes, &c. The entire machinery for a large rail-mill has also been sent out, as well as that for a plate and bar mill, together with twenty puddling furnaces. Two large blast furnaces of the Cleveland type, with a capacity of about 100 tons a day, are in course of construction on the slope of the Hamyang hills, opposite to the city of Hankow. The works will cover about 20 acres.‡

Cost of Production of Steel.—In his report of the cost of production of iron and steel in the United States, Mr. Carroll D. Wright § instances details as to cost obtained from a number of works making Bessemer ingots, rails, and miscellaneous steel.

The following is a summary of cost relating to the ton of steel rails :—

	Dollars.
Total cost of ore, limestone, coal, and coke	15·314
Cost of direct labour in producing the above materials	4·918
Per cent. of cost of direct labour in producing the above materials	32
Total cost of converting above materials and cinder into pig iron	2·482
Cost of direct labour in converting above materials and cinder into pig iron	1·576
Per cent. of cost of direct labour in converting above materials and cinder into pig iron	63
Total cost of converting pig iron and scrap and ferro-manganese into steel ingots	3·361

* *Iron Age*, vol. xlix. p. 12.

† *Ibid.*, vol. xlviii. p. 1115.

‡ *The Australian Mining Standard*, vol. vii. p. 88.

§ *Iron Age*, vol. xlviii. pp. 870-871.

	Dollars.
Cost of direct labour in converting pig iron and scrap and ferro-manganese into steel ingots	2·601
Per cent. of cost of direct labour in converting pig iron and scrap and ferro-manganese into steel ingots	77
Total cost of converting steel ingots into 2240 lbs. steel rails	3·685
Cost of direct labour in converting steel ingots into 2240 lbs. of steel rails	2·502
Per cent. of cost of direct labour in converting steel ingots into 2240 lbs. of steel rails	68
Total net cost of 1 ton of steel rails	24·666
Cost of direct labour in 1 ton of steel rails	11·597
Per cent. of cost of direct labour in 1 ton of steel rails	47

The total cost of the ton of billets was about 27½ dollars, of which the ingots cost 23 dollars. In the case of a works making boiler and tank plates the total cost was 47·2 dollars, the ingots used costing 31 dollars. The cost of the ton of wire at another works was 64·3 dollars, that of the materials used in its manufacture being 43·1 dollars; the ton of wire rods at another works cost 37·6 dollars, the materials having cost 28·3 dollars. This total cost includes labour, clerks, fuel, supplies, taxes, &c., and takes into consideration the value of any by-products obtained.

IV.—OTHER PROCESSES.

The Meyer Recarburising Process.—Demenge* describes a method of direct recarburising used by M. Meyer at the Dudelange works, in the Grand Duchy of Luxemburg, as applied to rail steel. Finely powdered anthracite mixed with 10 per cent. of milk of lime is moulded by hand into bricks of the ordinary building size, which are allowed to dry for a few months. When the charge in the basic converter is shown to be sufficiently dephosphorised by the ordinary method of testing, the slag is removed, and ferro-manganese, with 80 per cent. of manganese, in the right proportion for deoxidising the over-blown metal (0·5 per cent., or 90 lbs. for an 8-ton charge), is thrown in, a few minutes being allowed to enable it to melt and diffuse through the mass. During this time the ladle is prepared by throwing in 90 lbs. of the anthracite bricks, which are crushed by a rammer and distributed uniformly over the bottom. In pouring the charge, a workman is placed on each side of the crane platform, with a rake covered with refractory material, in order to prevent the slag in the converter flowing out with the metal, and the foreman, by means of

* *Le Génie Civil*, vol. xix. pp. 40-42.

the hydraulic mechanism, keeps the ladle slightly on the move both longitudinally and transversely, in order that the jet may impinge upon different parts of the surface successively. A violent reaction and evolution of carbonic oxide takes place when the metal meets the carbon, and for this reason the pouring must be done slowly at first, in order to prevent the ladle from boiling over; but at a later period the reaction is beneficial, for the stirring action of the gas promotes uniformity in the finished steel. When the pouring is completed, a portion of the slag is allowed to follow, so as to protect the metal against the action of the air, and the teeming into the ingot moulds follows at once. The ingots obtained are perfectly sound and compact. A cast intended for rail-making of the following composition—carbon, 0·52; manganese, 0·45; phosphorus, 0·075; silicon, 0·00; and sulphur, 0·013 per cent.—gives a tensile strength of 40·13 tons per square inch, with 18·5 per cent. elongation. The same process has been successfully applied to the production of the hardest steels with 1·5 per cent. of carbon. The economy realised is considerable as compared with the method of recarburising with spiegeleisen; 12 cwt. of the latter metal, which was formerly required for an 8-ton charge, being now replaced by 1 cwt. of dry coke, and the amount of ferro-manganese required is also reduced to the extent of one-half.

The Graff Direct Process.—According to Graff,* in his direct process the ore is mixed with carbonaceous material and reduced on the bed of a reverberatory furnace at a temperature sufficient to slag away the gangue and other impurities. The carbonaceous material used is coke crushed to the size of coarse sand and mixed with a wash of lime or clay. The hearth of the furnace is lined with coke coated in a similar manner. The charge consists of the coated coke mixed with 25 to 33 per cent. of ore, which is also crushed. After reduction, the sponge, which is fairly free from slag, is transferred direct to the bath in an open-hearth steel furnace, or it may be balled up and hammered.

New Methods of Refining Steel.—U. Le Verrier † discusses the rôle of the various agents added to steel during its manufacture by the acid and by the basic process. At first carbon was only added in the form of spiegeleisen, then ferro-manganese was used. Within the last

* *La Métallurgie*; *Colliery Guardian*, vol. lxiii. pp. 604-605.

† *Revue Générale des Sciences*, September 30, 1891.

two years other materials have been used, and the author refers to the use of ferro-silicon and to Darby's recarburising process. The analogy of this latter process to the cementation process is noted. Since the price of aluminium has been reduced, this metal has also been largely used, and has certain advantages over other additions, as it is a more powerful deoxidising agent than any other. It increases the fluidity of the metal, and it prevents in a greater degree than any other substance the formation of blisters. It diffuses itself readily through the molten iron, and its oxide is light, and readily rises to the surface without combining with other materials. Owing to its powerful action it need only be used in small quantities, so that the character of the metal is not changed. The increase in fluidity is marked, and may be explained partly by the heat generated by the oxidation of the aluminium and by the removal of the oxides from the iron, which may cause the metal to be pasty. As regards the action on the boiling of the steel, the question is very complex. The aluminium may act solely by its presence on the steel or on the gas, or it may prevent the beginning of the formation of bubbles. Aluminium can be used with advantage after a preliminary recarburisation with the aid of spiegeleisen. An alloy of aluminium containing 10 to 15 per cent. of silicon and 6 to 10 per cent. of iron might with advantage replace pure aluminium owing to the cheaper rate at which it might be produced by electrolysis. Finally, the author is of the opinion that the use of aluminium will become general in the manufacture of all varieties of steel, and that the Darby process will be used for hard steels.

FURTHER TREATMENT OF IRON AND STEEL.

Annealing Iron or Steel.—The usual process of annealing iron or steel is to heat the metal and to allow it to cool gradually. Attempts have been made to carry this out in a non-oxidising atmosphere, either by filling retorts with such gas or by sending a stream of the gas through the retort. The first method is liable to allow the metal to oxidise when the retort cools and air leaks in, whilst the second requires much gas. The improvements in these processes by Mr. H. K. Jones, according to Mr. H. C. Jones, consist in maintaining the non-oxidising gas in the retort at a constant pressure by connecting it to a gasholder or supply. There is thus practically no current nor inward leakage of air. This process has been in use for two years with success, and the work comes out perfectly bright and unoxidised. The retorts are made of wrought iron tubes suitable in size for the work, and may be connected direct to the gas mains.*

To determine if there were any injurious effects from the use of a carburetted gas, experiments were made by annealing in ordinary illuminating gas, in nitrogen, and by heating in the open fire and cooling in the ashes. The retorts containing nitrogen and gas were heated in the same furnace at the same time. Bending tests showed no difference, so tensile tests were resorted to. The results are given in the following table:—

Annealing in	Diameter in inches.	Breaking Load.		Elongation.	
		Lbs.	Lbs. per Square inch.	Total per Cent.	Per Cent. Gained.
Nitrogen . . .	0·156	1,187	62,140	29·12	22·00
Illuminating gas . . .	0·156	1,206	63,140	28·08	20·86
Nitrogen . . .	0·150	1,062	60,000	28·00	19·20
Illuminating gas . . .	0·150	1,069	60,400	27·20	18·40
Nitrogen . . .	0·156	1,095	57,330	30·88	23·76
Illuminating gas . . .	0·156	1,090	57,070	29·60	22·48
Open fire . . .	0·156	1,205	63,090	26·76	19·64
Unannealed . . .	0·156	1,855	97,120	7·12	...
Unannealed . . .	0·150	1,430	80,790	8·80	...

* *Engineering News and American Railway Journal*, vol. xxvii. pp. 5-6.

The effect of annealing steel castings is shortly described by Mr. L. Campredon.* Only castings of similar hardness and of nearly uniform size should be heated together, as each piece requires a distinct treatment depending on its quality. The heating should be gradual and uniform, and the cooling should be as slow as possible. The quality of the casting is always improved by reheating it, but the improvement depends largely on the character of the metal and on the way in which the operation is performed.

Annealing Ovens.—An illustrated description of some improved annealing ovens is given by J. A. Lencauchez.† The most important point in annealing is to use gas for heating, as then a perfect distribution of heat can be obtained, besides which it is more economical in fuel, in labour, and in the quality of the product obtained. Pots up to 2 feet in diameter, made of cast iron or of cast steel, are generally used to hold the work, but in the case of large objects the containers may be rectangular boxes from $1\frac{1}{2}$ to 2 feet high. The heating and cooling must be done slowly either inside or outside the oven. In the latter method the pots are supported on a carriage covered with brick which forms the bottom of the oven. The heating chamber is 22 to 26 feet in length and 4 to 7 feet in breadth, and will hold six to ten pots, which can be used from forty to sixty times if they are of good cast steel. The burners are placed in the middle of the furnace, and are arranged to supply rather more gas than air. The flames are led into a regenerator under the oven, where the combustion is completed with additional air. A regenerator of the continuous type is used, and the saving in fuel over ordinary furnaces is 40 to 50 per cent. If the cooling is done inside the furnace, only one regenerator is required for two furnaces; but when the cooling is performed outside, each furnace has its own regenerator.

Steel Castings in the United States Navy.—Mr. C. A. Carr ‡ gives particulars of some of the more important failures of steel castings in the American Navy. These castings were primarily adopted to decrease the weight, although in some cases the steel castings were heavier. For the steamer *Maine* the cast steel columns first received were all rejected and replaced by wrought iron. In

* *La Métallurgie*; *Colliery Guardian*, vol. lxiii. p. 510.

† *Industries*, vol. xi. pp. 591-592.

‡ *Journal of the American Society of Naval Engineers*, vol. iv. pp. 83-92.

the majority of cases defects were only discovered after considerable machining had been done. Some 36 tons have, however, been used, but these were selected from 52 tons, so that 44 per cent. were rejected. In another cruiser the rejections were about the same. The cost of rough steel castings for marine engine-work is said to be about four times that of cast iron, but greater allowance has to be made for machining, as much as 20 per cent. of the total weight being removed in the case of the valve chest-covers for the *Maine*. It is now five years since the Navy Department at Washington began to order steel castings, but it is said that even now American makers cannot supply a satisfactory article.

In his annual report to the Secretary of the United States Navy, Mr. G. W. Melville, the Chief of the Bureau of Steam Engineering, states that during the year under review most discouraging experience has been had in connection with steel castings. In some cases parts designed of cast steel have been built up of forged or rolled steel; in others, the castings have been reinforced with plates of rolled steel; and in others again, the castings have been made abnormally heavy and then reduced to size in a shaping or planing-machine. How little progress has been made in the production of steel castings was evident in a marked degree in the manufacture of the engine columns of one of the vessels constructed. They were perfectly plain, hollow columns, and in cast iron would have been the simplest kind of work; in cast steel every one of them was so imperfect that not one of those made could be employed.*

Handling Ingots and Moulds in Bessemer Steel Works.—

An apparatus is described with the aid of illustrations by Mr. G. Curtis† for handling ingots and moulds in Bessemer steel works. A short length of a cable tramway is laid on the floor of the converting house within range of the ingot cranes. The two tracks converge into one just before the ingot extractor. The movements of the trucks and the extractor are controlled by one operator. After the truck passes the stripper, the hot mould is removed by a crane, which brings a cold mould on its return to replace the hot one. This crane is manipulated by a boy, and while it is at work another light overhead travelling crane removes the stripped ingot to the pits. This

* *Iron Age*, vol. xlviii. p. 1033.

† *Transactions of the American Institute of Mining Engineers*, Glen Summit meeting (advance proof).

second crane is worked by rope gearing, and it can completely cover the area occupied by the pits, and the doors covering the pits are provided with handles arranged so that they can be opened by the man on this crane while it is being stopped. The ingot stripper is of the vertical type and consists of two hydraulic cylinders connected by heavy steel bars. The upper ram is caused to descend on to the ingot by exhausting water from its under-side. During the descent, water not under pressure flows in above the ram and is imprisoned by a check-valve as soon as the ram stops. The lower cylinder is then put into operation and lifts the movable seat on which the mould rests. The ingot is thus held while the mould is freed. The moulds are stored round the mould crane, and may be placed on open seats supported on posts arranged over a circular pit 4 feet deep. This arrangement permits of their ready inspection and repair, and also allows a current of air to play freely round the moulds so as to cool them rapidly.

Mr. F. Heron,* of the Phoenix Iron Company, Pennsylvania, has designed an ingot manipulator, and this has now been in successful use at the Phoenixville Ironworks for some time past. This manipulator consists of a carriage mounted on V-shaped rails run transversely to the line of feed of the rolls. This carriage supports a vertical hydraulic cylinder made in two parts, the lower of which is removable for repairs. Attached to a hollow plunger is a cross-head guided by two rods and carrying four fingers. The carriage is moved laterally by a horizontal hydraulic cylinder. The particular feature of the manipulator is a lower hydraulic cylinder, the piston of which is in reality the water supply pipe of the vertical cylinder on the carriage. As the carriage is moved to and fro by the upper hydraulic cylinder, this pipe travels in the smaller and lower hydraulic cylinder, always maintaining its connection with the water supply and dispensing with the use of valve arrangements generally in use in ingot manipulators.

Solidifying Steel Ingots.—Mr. J. Munton,† manager of the Chicago Tire and Spring Works of Melrose, Illinois, has devised a method for obtaining solid ingots. This consists in allowing the ingot to solidify under a bath of slag, which is poured into the mould before the steel has had time to set. The ingot thus treated is stated to be dense and homogeneous and free from pipes and blow-holes. The loss through crop-ends is greatly reduced.

* *Iron Age*, vol. xlix. p. 110, two illustrations.

† *Ibid.*, vol. xlviii. p. 1082.

Casting Plate Slabs.—Mr. J. Parkes * proposes to cast steel slabs free from blowholes, as closely as possibly approximating to the size of the boiler or ship plate desired. This is effected by causing the metal to rise upwards through a series of slab moulds of different and gradually diminishing sizes.

Hammer for Piling Scrap Iron.—An illustration is given † of a hammer designed by Mr. R. R. Gubbins for consolidating scrap iron into piles suitable for steel-melting or for heating and rolling. Moulds the size of the required piles are secured on the rim of a revolving table and are filled with the metal. Each mould is then brought under a drop-hammer which weighs 15 cwt., and falls on to an anvil weighing 4 tons, and a few blows are given to compress the metal. Piles 20 by 7 by 10 inches and weighing $1\frac{3}{4}$ cwt. can be made at a cost of 2s. per ton.

Electric Welding.—Illustrations are given ‡ of the gyrating carbon machine which is used in the Bernardos system of electric welding. The machine is adapted to weld tubes from 6 inches up to 4 feet in diameter, and up to 16 feet in length. It is self-contained and runs on rails. The machine consists of two parts—one the electric heating device, and the other the hammer for completing the weld. Each part is driven by a separate motor. Full details of the construction of the machine are supplied.

The Bernardos system of welding by the electric arc is in use at the Coombe Woodworks, Halesowen, near Birmingham,§ for the manufacture of butt-welded galvanised wrought iron pipes and fittings, and has replaced the system formerly in use there of welding by the aid of a blowpipe. The limit of gas-welding used to be pipes of 6 inches in diameter, but 12-inch fittings $\frac{5}{16}$ -inch thick have been welded by electricity and tested to 800 lbs. per square inch. A compound Davey-Paxman horizontal engine, giving 100 indicated horse-power at 100 revolutions, is employed to drive three Crompton dynamos giving 140, 150, and 150 volts and 150, 150, and 200 amperes respectively. Carbon-tipped brushes are used, and the dynamos working in parallel are used to charge a set of accumulators consisting of 1800 cells of the

* *Iron Age*, vol. xlviii. p. 54, one illustration.

† *Industries*, vol. xii. pp. 531-532.

‡ *Engineer*, vol. lxxiii. pp. 168-169.

§ *Electrician*, vol. xxviii. pp. 190-200; *Engineer*, vol. lxxii. p. 756; *Engineering*, vol. lii. p. 529.

Planté type with 9 by 7 inch plates. The usual current for each arc is 150 amperes at 70 volts. The positive lead is clamped to the table holding the work, and the negative pole consists of a carbon pencil held in a metal clamp with a wooden handle and a shield faced with asbestos to protect the hand. The arc may be drawn out to a length of 6 inches and $1\frac{1}{2}$ inches in diameter. Ordinary welds are made by placing a piece of iron or steel weighing a few ounces on the work and playing the arc on it till it begins to run, when the part is hammered in the usual way. In one instance the arc tool was used twelve or fourteen seconds, five or six seconds were spent in hammering, and 2 to $2\frac{1}{2}$ inches of the seam were welded at each heat. Hardly any slag or scale was to be seen.

A pipe-welding machine has been built for making tubes from thin sheets. In this machine the carbon-holder rotates in a circle of $2\frac{1}{4}$ -inch diameter at 300 to 400 revolutions per minute, and has also a reciprocating motion of 4 inches at the rate of thirty strokes a minute. The holder is driven by a small electric motor and heats a considerable area of the work, which is then transferred to a Player hammer, also driven by an electromotor, to complete the weld. The workmen are protected from the arc by screens with red glass windows.

In making complicated fittings, the parts required are cut from sheet metal by the use of the arc, leaving a somewhat ragged cut of $\frac{1}{8}$ -inch. In spite of this, the system has considerable advantages. Repairing work can also be done. In case of a defective casting, the flawed part is melted out and filled again by melting or burning in pieces of metal. Another operation that can be performed by the aid of the arc is the flanging of pipes. Either the flange can be welded on or the pipe may be heated by the arc and turned out as it is revolved.

A New Welding and Tube-Shaping Process.—A new process for welding and for shaping tubes, devised by Mr. J. H. Bevington, has recently been described.* The process consists essentially of forcing together the ends of the material to be welded in the interior of a revolving converging die, and utilising the heat thus produced by friction to effect the weld. The machine is essentially a lathe with a hollow spindle in which the die is secured, and a movable tail-stock also with a hollow spindle. For welding wire or rods up to one inch in diameter the ends are scarfed; one end is held in the die by a clamp

* *Industries*, vol. xii. p. 368, with four illustrations.

outside the head-stock, and the other end is clamped in the tail-stock and pressed against the first-named end while the die is revolved. The heat generated by the friction and the pressure then welds the material. For shaping or making tubes, the tube or skelp is forced into the revolving die.

The Manufacture of Mannesmann Tubes.—The development in the manufacture of Mannesmann tubes is described by Krause * with reference to their applications to military purposes, such as steel projectiles, ordnance tubes, rifle barrels, and steel lances; also to the manufacture of carriage poles, telegraph poles, and water conduits. Specimens were shown by the author to illustrate the resistance to bending in these tubes. The demand for tubes to be used in the manufacture of cycles is already overtaking the productive capacity of this branch of the works, and a very large number of telegraph poles made from these tubes are in use, or are being ordered for East Africa, Asia, and Holland. Brass and copper tubes have also been successfully made by this process.

Riveted Steel Pipes.—The use of steel for the manufacture of pipes, although not so well known as in its other applications, promises, according to Mr. D. J. R. Duncan,† to supersede older methods of pipe manufacture from wrought or cast iron. Cast iron is still largely used in England, although steel pipes can be made at competing prices; but in America riveted pipes cost less than imported cast pipes. Steel pipes have a great advantage over wrought iron pipes, as steel plates can be made larger, so the number of rivets and joints are very greatly lessened, with a proportionate decrease in punching and caulking. The tensile strength is also much greater, and the pipe is more durable and less liable to corrosion. The factor of safety used in America is very much lower than in England, and the author is of opinion that a definite standard should be adopted, with calculations based on an ultimate strength of 60,000 lbs., and a safety factor of 5. Formulæ are given for determining the sizes of the pipes and thickness of metal required.

Riveted steel water-pipe of five feet internal diameter, laid in

* Paper read before the Polytechnic Society of Berlin, through *Industries*, vol. xii. p. 150.

† Report of the American Waterworks Association, Philadelphia, 1891, p. 45; *Minutes of Proceedings of the Institute of Civil Engineers*, vol. cvii. pp. 478-480.

connection with some Paris waterworks, is described by G. Lavergne.* The pipe is of mild rolled steel, 0.235 inch in thickness, and designed so that the working stress shall not exceed 3.8 tons per square inch. Minute details are given of the hot and cold tests used for proving the material, and of the size of the test-pieces required.

The Manufacture of Wire Rods.—Mr. P. R. Dillon † states that the rod-mill at the well-known works of Messrs. Carnegie, Phipps, and Co., in a ten-hour shift made 321,660 lbs. of rods from 342,960 lbs. of metal charged; and in two other consecutive ten-hour shifts the rods made weighed 621,110 lbs. from 661,820 lbs. of metal. The above is stated to be the greatest "record" yet obtained in the case of a rod-mill.

Bending, Straightening, and Flanging Machines.—Illustrations are given ‡ of a horizontal set of rolls for bending ships' or other plates up to one inch thick and 21 feet long in the cold. The machine is self-contained, and a small engine is used for raising or lowering the top roll. The rolls are of cast iron, the top one 31 inches in diameter, the two below each 21 inches, and the latter are supported from below by friction bowls. The total weight of the machine is 66 tons.

A horizontal set of bending rolls is also illustrated,§ in which the plate can be withdrawn by tilting the top roll. One of the bearings for the top roll is mounted in trunnions to allow this, and the roll is prolonged beyond the bearing, so that it can be depressed by a screw. The machine is designed to take plates up to $\frac{3}{4}$ -inch in thickness, and 10 to 12 feet in width. The lower rolls are stiffened by supporting rollers, and the top roll is driven by friction.

Illustrations are also published || of a set of bending rolls consisting of four forged rolls, the top and bottom pinching rolls being 24 inches in diameter, and the side ones 20 inches. Cold mild steel plates $\frac{3}{4}$ -inch thick can be bent to a radius of 15 inches for the full length of the rolls. The pinching rolls are adjustable to pinch plates from $\frac{1}{16}$ -inch to 2 inches in thickness, and sufficient power is provided to bend $\frac{3}{4}$ -inch plates to the above radius at a single pass.

Another form of plate-bending rolls is that designed by Messrs

* *Le Génie Civil*, vol. xix. pp. 122-123, three illustrations.

† *Iron Age*, vol. xlviii. p. 940.

‡ *Engineer*, vol. lxxiii. p. 96.

§ *Engineering and Mining Journal*, vol. liii. p. 379.

|| *Iron Age*, vol. xlviii. p. 932, with supplementary sheet of engravings.

Wickes of East Saginaw, Michigan. The rolls are driven by double horizontal engines completely controlled by one lever. The top roll is raised and lowered by power, either end being raised or lowered independently when desired. This mechanism is driven by a friction attachment controlled by a lever under the foot of the operator, and is so designed that should the top roll be brought into contact with the bottom rolls it would be impossible to break any of the gearing. This friction attachment also admits of a change in position of the top roll while the plate is being passed through and the machine is in motion. By this device plates may be rolled with much greater rapidity than is possible by any of the methods now in use.*

Illustrations of large bending rolls are published in the *Iron Age*.† The adjustment of the two side rolls and of the lower pinching roll is effected by means of two engines. The upper pinching roll is driven by a separate pair of engines. All the adjustments can be made independently of each other—that is, either end of either side of the side rolls can be elevated or lowered as may be desired without changing the position of the other end. The diameter of the pinching rolls is 21 inches and of the side rolls 20 inches; the weight of the four rolls is 84,000 lbs., the total weight of the machine is 300,000 lbs., and it will bend a plate $1\frac{1}{4}$ inch thick and $15\frac{1}{2}$ feet long.

Vertical bending rolls capable of bending armour plates up to 10 feet wide by $1\frac{1}{2}$ inch in thickness are illustrated.‡ The rolls are of forged steel; the bending roll is 18 inches and the side rolls 15 inches in diameter, and the housings are arranged to leave the front of the machine free. The side rolls in this machine are adjustable by a pair of independent engines arranged so as to feed the ends of the rolls independently, so as to bend straight or in wind. All the rolls are positively driven, and calendering action is prevented by the introduction of clutches into the gearing of the side rolls, the clutches allowing of the differences of speed required. The middle roll thus does most of the work in driving the plate, and its gearing is proportionately heavy.

A plate and angle bending machine of Austrian manufacture is illustrated in *Engineering*.§ The standards are mounted on wrought iron girders, and there is no cast iron bed-plate. One standard can be

* *Iron Age*, vol. xlviii. p. 1120, one illustration.

† Vol. xlviii. p. 888, supplementary page of engravings.

‡ *Engineering*, vol. lii. pp. 645-651, one illustration.

§ Vol. liii. p. 241.

withdrawn by screw-gearing to clear the rolls for the removal of a cylindrically-bent plate. Small rolls at the end of the machine are used for bending angle iron. Spur-gearing running in oil is used. The rolls are 12.6 inches in diameter, and will take plates 0.79 inch thick, and 11½ feet wide. The machine weighs 13 tons.

An illustration is given of a four-roller machine for bending angle and T iron up to six by five inches.* The two outer rollers are adjusted simultaneously by hand-gearing; the middle or driving roll is driven by spur and bevel-gearing under the table, and the fourth roll grips the material.

A powerful machine is illustrated † for flanging boiler flues from 22 inches to 4½ feet in diameter, by 18 inches to 4½ feet deep, and of mild steel plate three-quarters of an inch thick. The flue is gripped on a rotating chuck-plate by four jaws, and its top end supported by two guide rollers. The chuck-plate is revolved and the flue is bent over by a flanging roller, which is turned down by screw-gearing. The machine will put on a 4½-inch flange at one heat.

The effect of flanging steel at various temperatures is described by Mr. C. B. Blackwell.‡ Two samples of steel were bent and twisted, one in the cold, the other at a red heat. The other end of each piece was bent at a temperature of 600° F., which corresponds to a blue colour on a clean surface. Numerous cracks were developed under the latter treatment, though the steel in other respects worked well.

At the Tredegar Ironworks, Richmond, United States, there is erected a machine for bending link blanks, such as are used for couplings. The machine cuts the link blank from a hot rod, the ends of the rod are scarfed for welding, and the blank being brought to the proper shape by being bent round a mandrell by rolls, the ends overlapping. The whole operation is all done in one heat.§

Mr. J. R. Jones|| has designed a machine for straightening rolled tapered axles. After the rolls have imparted the desired shape to the axle, it is straightened in the machine at the same heat, receiving no injurious effects, as in a gauge press, and requiring no turning in a lathe. The machine consists of two superimposed rolls and two smaller

* *Industries*, vol. xi. p. 457.

† *Iron and Coal Trades Review*, vol. xlv. pp. 74-75.

‡ Paper read before the Master Mechanics Association, Cape May, New Jersey, June 1891; *Railway Engineer*, vol. xii. p. 205.

§ *Iron Age*, vol. xlviii. p. 812, six illustrations.

|| *Ibid.*, vol. xlviii. p. 976, two illustrations.

adjustable rolls balanced by weights or springs suitably placed for acting on the axle as it passes through the main rolls.

Planing and Milling Machines.—In the Richards planing machine an overhanging arm extends in such a manner that with a straight-cutting tool it will plane 36 inches wide and 8 feet long. This arm is made very deep and is strongly braced, and carries a slide that will plane down 24 inches. The tool slide has automatic down and angular feed, and is driven by a double-threaded screw with pulleys geared direct on the end. The pulley driving the tool cutter is 24 inches in diameter, the return pulleys being 14 inches in diameter, causing a quick return. The machine has legs 2 feet wide at the bottom, forming a space several inches wide in line with the flat face of the bed. This space has a large T-slot, so that the plates are supported at the lower ends, and between the legs there is bolted a heavy cast iron beam that ties them together, while the T-slot on its side coincides with the T-slots on the legs. All the T-slots that support the plates and tables have planed up to suit them heavy steel strips, into which studs are firmly screwed and fastened, thus avoiding the wear and tear of the bottom of the slots, such as results when bolt-heads are used.*

A planing-machine is illustrated† in which the table is driven by an internal and external wheel, the internal teeth are in gear with a driving pinion directly under the rack, and the external teeth are in gear with the rack itself.

An illustration is given ‡ of a large combined horizontal and vertical planing-machine, capable of planing 22 feet horizontally, 18 feet vertically, and 3 feet transversely. It weighs close on 100 tons. The base plate, which is 2 feet in depth and ribbed, extends 10 feet in front of the tool. The uprights are hollow castings, 12 feet long at the base and 12 feet high, stayed together at the back. The upper and lower slide beds are each 28 feet long by 2 feet wide.

The forms and the use of milling tools and appliances generally are discussed by Mr. R. R. Lister.§ The hole in the cutter is chambered out, so that it fits its spindle at two narrow surfaces only, which can be more readily ground to fit than if the bearing surface were solid. A

* *Iron Age*, vol. xlviii., one illustration.

† *Iron and Coal Trades Review*, vol. xlv. pp. 108-109.

‡ *Engineering*, vol. liii. pp. 198-200.

§ Paper read before the Manchester Association of Engineers, through *Engineering*, vol. liii. pp. 27-28.

joint cut at an angle to the plane of the cutter allows packing to be inserted, so as to keep it of standard width. The face of the teeth should preferably be radial, as then they will not choke, and the teeth should have a pitch of from $\frac{5}{16}$ to $\frac{3}{8}$ inch. The teeth should preferably be spirally cut in such a direction as to hold the work down. High-class tool steel or Howell's case-hardening steel for larger cutters have been used by the author for these cutters. The teeth should be kept sharp by grinding with an emery wheel, care being taken not to draw the temper. The plain cylindrical cutter up to $3\frac{1}{2}$ inches in diameter is, on the whole, the best to use wherever it is applicable. Several tables are given by the author to show the speed of the cutter and the rate of feed, as drawn from actual practice. One of these tables is given below :—

Class of Work.	Diameter of Cutter. Inch.	Depth of Cut. Inch.	Width of Cut. Inch.	Revolutions per Minute.	Cutting Speed in Feet per Minute.	Feed in Inches per Minute.
Mild steel coupling rods—						
Roughing out . . .	...	$\frac{1}{4}$	5	...	50	$\frac{3}{4}$
Finishing cut . . .	...	$\frac{1}{8}$	5	...	60	1
Steel rails . . .	7	1	2	15	32	$\frac{1}{4}$
Wrought iron spring buckles	12	$1\frac{1}{4}$	2	15	47	$\frac{1}{4}$
Cast steel horn blocks . .	6	$\frac{1}{4}$	$2\frac{1}{8}$	14	22	$\frac{1}{4}$
Wrought iron nuts (with two side cutters . . .	6	$1\frac{1}{8}$ — $\frac{1}{2}$	...	30	47	$\frac{1}{4}$
Cast iron steam-chest covers	3	...	...	25	20	$\frac{1}{8}$

The speed of the tool can be much greater than in the case of other tools, as the teeth are not in contact very long with the metal, and so have time to cool. The machine itself should be perfectly free from vibration, and should be supplied with plenty of power. The feed should be easily adjustable independently of the speed of the cutter, so as to get the maximum of economy and good work.

Illustrations are given * of a vertical milling-machine with a $2\frac{1}{2}$ -inch spindle vertically adjustable. The table is 54 by 28 inches broad and has a traverse of 54 inches. There is also a longitudinal adjustment and a quick hand movement. The speed of traverse is adjustable up to $1\frac{1}{2}$ inch per minute, and the cutter may be as much as 5 inches deep.

An illustration is given † of a heavy standard milling-machine weighing about 10,000 lbs. The spindle runs in hard bronze boxes, the front bearing being conical and $6\frac{1}{2}$ inches in diameter. It is driven by a 4-step cone for a $3\frac{1}{2}$ -inch belt, through gearing in the ratio of 16

* *Engineer*, vol. lxxiii. p. 7.

† *Iron Age*, vol. xlviii. p. 1155.

to 1. The gear on the spindle is 30 inches in diameter, $3\frac{1}{2}$ inches face. There are eight properly arranged speeds, from that required for a cutter 4 inches in diameter to one of 20 inches. The overhanging arm is 8 inches in diameter and can be removed for the use of face cutters or other purposes. The head has a horizontal movement on the top of the column for adjustment of cutters, thus dispensing with one joint below the table. The knee bearing on the standard is 20 inches wide, 26 inches long, and the table is 72 inches long, 14 inches wide, and at the lowest position from the top is 24 inches below the centre of the spindle. Its bearing in the knee is 48 inches long, and 14 inches wide.

Boring and Drilling Machines.—A radial drill has been designed by Mr. J. H. Hamilton * to reduce the number of settings required for the work. There are two drill spindles, one is mounted on a radial arm on a vertical standard in the usual way, and the other is mounted on an arm carried by a horizontal standard so that the two spindles are at right angles. The arm for the latter spindle is counter-balanced, and the counterbalance weight is moved simultaneously with the drill-carriage when it is adjusted on the arm by means of a rearward continuation of the traversing screw with a left-hand thread. The drills are driven independently.

A machine is illustrated † for drilling the holes in boiler-flue flanges. The flue is held on a revolving chuck-plate between two standards, each of which carries a vertical drilling mechanism. Both of these can be fed simultaneously, and the drill, besides its vertical motion, has the required lateral travel, &c.

An illustration ‡ is also given of a horizontal boring and drilling machine. The work is adjusted in a vertical direction by screws which raise the slide rest in which it is fixed, and which provides for the transverse adjustment and feed. The driving-head is arranged as in a lathe with a five-step cone and back-gear allowing fifteen changes of speed. The main spindle is 5 inches in diameter and has a travel through its cone up to 60 inches. The feed is automatic.

A double-gearred vertical drilling-machine with several novel devices has recently been produced. The table is supported by a strong vertical hinge so that it can be turned to one side in order to allow large pieces of work to be placed on the base. §

* *Engineering*, vol. lii. p. 639, one illustration.

† *Iron and Coal Trades Review*, vol. xlv. pp. 74-75; *Engineer*, vol. lxxiii. p. 68.

‡ *Engineering*, vol. liii. p. 87.

§ *Engineer*, vol. lxxiii. pp. 23-24.

A radial drilling-machine for heavy work is illustrated in *Industries*.* The arm is adjustable through a height of 3 feet 4 inches, and will admit work 6 feet high. The spindle is $2\frac{5}{8}$ inches in diameter and has a radius of 6 feet from the centre of the column.

A self-contained portable vertical-boring machine has been designed for boring cylinders, especially marine-engine cylinders in position. It will bore up to 8 feet in diameter by $6\frac{1}{2}$ feet deep.†

Mr. R. Bolton ‡ describes the square drilling-machine, and shows the uses to which this machine may be applied in forming correctly shaped holes of various forms for different purposes. The use of this machine will obviate the use of a number of stereotyped devices in mechanical construction, now that it is possible to attain the same ends in a different manner. The machine drills round holes as well as it does square or other shaped holes, and various sizes of holes may be drilled with the same machine with a perfect adjustment of diameter. Taper holes, larger at the bottom or at the top, can also be made, and the machine will work in iron, brass, or stone. Other attempts at square drilling-machines are also described and compared with the latest forms of universal machines. In the discussion it was stated that the machine is being employed to bore locomotive axle-holes having a diameter of 10 inches, and that it can bore perfectly square holes as small as $\frac{3}{8}$ inch. Holes up to 3 inches in depth have been bored, and in large holes at least there is no difficulty in removing the cuttings.

Mr. S. Couper,§ in discussing the applications of electricity to the drilling of metals, gives his experience of a self-contained drill of the size known as the inch-driller. The total weight of the machine, with its attached motor and framing, is 314 lbs. The motor runs at 2000 revolutions per minute, and drives the drill through a second motion shaft at 125 revolutions. The holding power of the electro-magnet is 1650 lbs.; this, however, should be greater as its grip is slackened, by putting a heavy feed on the drill, especially when drilling upwards, when the magnet has to support the weight of the machine. A greater variation in the speed ratio would also be desirable. The best results were obtained by running at a high speed with a fine feed. The cur-

* Vol. xii. p. 221.

† *Industries*, vol. xii. pp. 122-123.

‡ Paper read before the Society of Civil and Mechanical Engineers, January 6, 1891, through the *Iron and Coal Trades Review*, vol. xlv. p. 76.

§ Paper communicated to the Graduates section of the Institution of Engineers and Shipbuilders, Glasgow, through the *Electrician*, vol. xxviii. pp. 305-306.

rent is taken through the shops by overhead wires and flexible branch leads, and is supplied at twelve to fourteen amperes and a hundred volts. In ordinary working the following results can be obtained :—

Amperes.	Diameter of Hole.	Thickness of Plate.	Material.	Time.
12	Inches. $1\frac{1}{4}$	Inches. 1	Iron	Seconds. 120
12	1	$\frac{3}{4}$	Steel	75
14	$1\frac{1}{2}$	1	Iron	90

The great advantage of these machines is their portability and their capability of boring holes in the centre of large plates or other inaccessible places. Finally, the author discusses the various methods of working, and gives details of the comparative costs.

American Steel Rails.—The *Railroad Gazette* * has instituted a series of inquiries with a view to ascertain what changes are in progress in the United States in the manufacture of rails. It finds that the section rolled has not been appreciably affected by the various reports which have been published on this subject. The weight of the rail seems to be increasing, and so too does the percentage of carbon in the metal rolled. Thus one of the rail-mills uses now the following percentages of carbon in the metal for rails of the weights mentioned :—

Weight of Rail, Lbs. per Yard.	Carbon per Cent.
60	0.40-0.45
70	0.45-0.50
80	0.45-0.60

The average percentage of carbon in the whole of the mill's output is about 0.55.

Two rails which had been treated by the Harvey cementation process have been in use on the line of the Delaware, Lackawanna, and Western Railway at Scranton since August 1891. They are stated to have shown less wear and flow of metal than other rails subjected to use under the same conditions. The following are the results of carbon determinations made from metal at different depths from the rail face : †—

* Vol. xxiii. p. 672.

† *Iron Age*, vol. xlix. p. 118.

Depth from Face.	Rail I.	Rail II.
Sixteenths of an Inch.	Carbon per Cent.	Carbon per Cent.
1	0·76	0·76
2	0·42	0·42
3	0·33	0·31
4	0·30	0·30
6	0·30	0·30
8	0·33	0·30
10	0·30	0·27
12	0·30	0·28
16	0·27	0·26
20	0·27	0·26
24	0·27	0·25
Flange	0·24	0·27

According to Mr. P. H. Dudley,* some sixty-six miles of rails of 95 lbs. per yard were rolled and laid by October last in America. The carbon contents of these rails was 0·6 per cent. The head and base are wide, so that some difficulty was expected in rolling this section, but with the experience gained in rolling 75-lb. rails, also containing 0·6 per cent. of carbon, and not more than 0·06 phosphorus, no great trouble occurred. For planing these rails, self-hardening steel tools were required; but none of the rails broke in handling, nor since they have been put into use. Particulars are given of drop tests with these rails with a tup of 2100 lbs. falling 20 feet on a rail with supports 3 feet apart. Sections of these two rails are appended.

The Use of Old Rails in India.—Old rails are now being used as telegraph posts along the line of the Great Indian Peninsula Railway. They are stated to be very effective, being both cheap and durable. An extra piece of rail is bolted to the long rail at its lower extremity, in order to counteract the top weight. This piece is generally from 4 to 6 feet long for an ordinary telegraph post. Sometimes two pieces are necessary for specially long poles. This end is then buried in the soil, the ground is well rammed at the base, and the pole is at once ready for its fixings. The brackets for these rail posts are of wrought angle iron, a piece of about 2 feet long being bolted to the post, and the ends bent somewhat to contain the insulator pins. This presents a very neat appearance, and keeps the wires well apart, so that they do not come in contact during high winds.†

* *Railroad Gazette*, vol. xxiii. pp. 778-779.

† *Indian Engineering*, vol. x. p. 287.

Metal Sleepers.—Steel sleepers made by the Standard Metal Tie Company have been in use on the line of the Chicago and Western Indiana Railway since October 1889. Mr. J. W. Clarke * states that the total expense for 1000 lineal feet of track laid with this steel sleeper was 45½ dollars in nineteen months, most of which expenditure was due to the necessity of raising the roadway to the level of the adjacent wooden sleepers. On the other hand, the cost for labour alone for 1000 feet of similar track laid with wooden sleepers was 210¼ dollars. The track laid with metal sleepers gave general satisfaction.

Steel Waggon Axles.—P. Kreuzpointner † discusses the manufacture of these axles. They should be of open-hearth steel, as suitable Bessemer metal would be too high in price. Next to the proper grade of steel for waggon axles, it is essential that the mechanical treatment of the steel for axles be such as not to deteriorate its quality. Much mischief may be done by a careless and improper treatment of the steel for axles by unequal heating and forging. In axles thus carelessly treated a difference in strength of from 4000 to 7000 lbs. per square inch and of 10 per cent. in elongation may be found within a distance of 2 inches.

The custom, sometimes followed, of heating the end of an axle red hot in order to straighten the journal is a most reprehensible one. Unless an axle so treated is annealed afterwards, this unequal heating produces a different structure at every inch from the heated end to where the axle remained cold. Especially is that portion brought to a dangerous condition where the red heat turns into what is called black or blue heat and from there to the cold. The injurious effects of blue or black heat on steel are now well recognised, and these effects do not disappear altogether when the steel is cold. That portion in an axle remains more or less brittle, with its qualities to resist dynamic forces, shocks, and blows seriously impaired.

Throwing red-hot axles on the wet ground or into water, or piling them where the wind, snow, or rain can cool them, should be carefully avoided, as internal strains are produced in this way. Blow-holes should be absent, and the metal should not be worked by light hammers.

The best grade of steel for a railway axle is one that is hard enough to resist the heaviest blows, but with enough ductility or flow in the metal to yield a little—to cushion the blow. The metal must

* *Iron Age*, vol. xlviii. p. 712.

† *Ibid.*, vol. xlviii. pp. 795-796.

neither be too hard nor yet too soft, as in the former case it is apt to fracture suddenly, and in the latter fatigue is likely to show itself too soon. The axle must have a high elastic limit. Too much confidence should not be placed in the tensile test, and the chemical analysis, as far at least as the carbon is concerned, must be considered only in conjunction with the kind of work and the temperatures to which the metal has been subjected.

The influence of the structure of the metal on the character of the axle is also considered, especially as regards the fact that a mass of steel is not a uniform material.

The question of the fracture of an axle depends on many considerations. The process of fracturing probably takes place in the following manner:—The metal having become fatigued, the outside fibre is strained beyond the yield point on the tension side and a separation of these fibres takes place. During an interval of rest the remaining portion of the axle recovers sufficiently to do the necessary work, but the reduced section has to carry a heavier burden, and the process of fatiguing and separation being soon repeated, the metal will finally break, after two or three, or it may be ten, such periods of rest and of fatigue. Axles should always be very carefully annealed.

Wheel-Rolling Mill.—The mill designed for rolling wheels by Mr. J. R. Jones, of the Pencoyd Ironworks, Philadelphia, is illustrated in the *Iron Age*.* The wheel produced has, it is claimed, a web and rim of uniform section, dense but fibrous. The ingot is worked into shape much in the usual manner of such machines by the action of a series of revolving rolls.

The Munton Tire-Mill.—This mill is in successful operation at the works of the Chicago Tire and Spring Company. The process entirely dispenses with hammering in making locomotive or other steel tires. The ingot is cast with a hole cored out large enough to admit a small roll. The ingot is heated and taken to the rolling-mill, where its top, with its imperfections, is sheared off by the rolls, and the bloom left of a given weight. At the same heat and by the same operation the bloom is also roughed-out by the roughing rolls of the mill and edged down by horizontal rolls. The bloom is reheated and placed in the tire rolling-mill, where it is rolled and finished to the exact inside and outside diameter required. The mill is so constructed

* Vol. xlviii. p. 493, four illustrations.

that on it a bloom can be rolled back to a smaller diameter. This also applies to a finished tire.*

The Harvey Cementation Process for Armour Plate.—In this process† an armour plate, consisting originally of very mild steel, is cemented in such a manner as to produce a face of very hard steel, the steel becoming gradually less hard from the face towards the unaltered soft back. Such a plate of mild steel, containing from 0·10 to 0·35 per cent. of carbon, is placed upon a bed of finely-powdered dry clay or sand, deposited upon the bottom of a firebrick compartment erected within the heating chamber of a suitable furnace. The compartment is then partially filled up with granular carbonaceous material, which, having been rammed down upon the plate, is in turn covered with a stratum of sand, and upon this there is laid a covering of heavy firebricks. The furnace is raised to an intense heat, which is kept up for such a period of time as may be required for the absorption by the metal adjoining the upper surface of the plate of an additional 1 per cent. of carbon. The temperature of the heating chamber outside the treating compartment is raised to about that required to melt cast iron, and is kept up for a greater or less length of time, according to the depth of the stratum of steel which it is intended to charge with an excess of carbon.

The following is an example of this process:—A plate 10½ inches in thickness, composed of a steel containing 0·35 per cent. of carbon, may be charged with additional quantities of carbon, gradually varying in amount from about 0·10 per cent. at a depth of 3 inches beneath the surface of the exposed side of the plate to 1 per cent. at the surface by a continuance of the treatment for a period of 120 hours after the furnace has been raised to the required temperature.

The depth to which this increased degree of carburisation can be allowed to penetrate increases with the thickness of the plate. This penetration is dependent not only on the temperature of the furnace and on the length of time the plate is exposed to the cementation process, but it is also greatly facilitated by the continuous firm compression of the carbonaceous material against the plate. The plate, when considered sufficiently carburised, is freed from its carbonaceous covering, allowed to cool to a dull cherry-red, and then hardened. In

* *Iron Age*, vol. xlviii. p. 884. See also *Portefeuille Economique des Machines*, 1892, pp. 65-68.

† *Iron Age*, vol. xlviii. p. 736; *Iron and Coal Trades Review*, vol. xliii. p. 615.

this connection it is interesting to note that such plates hardened by a spray jet gave unequal results on trial, the upper corners showing resistance to penetration by shot, while the bottom of the plate was penetrated. This was due to the heated water from the cooling of the upper portion of the plate acting as a protective coating to the lower portion during the cooling, thus preventing rapid cooling.

Hardening Armour Plates.—The process designed by Captain T. J. Tressider for hardening armour plates consists in subjecting them to a douche or spray of cold liquid, which is supplied by a great number of small jets. If one side of the plate only, such as the steel face of a compound plate, is to be hardened, the plate is supported in a tray so that its lower surface is at some distance above the tray. The plate is cambered, so that it may not warp during treatment. It is heated, and the spray is then directed on the upper surface, which has to be hardened. The excess liquid gathers in the tray and cools the lower side of the plate. If the plate is only to be partly hardened or tempered, the spraying operation is interrupted and the plate allowed to cool naturally to the requisite temperature before the spray is again applied. Both sides of the plate may be hardened by spraying on both sides, or a current of moist air may replace the spray. Part of the plate may be kept soft by shielding it from the direct cooling action.*

New Process for Protecting Iron and Steel.—A process has recently been introduced for coating iron and steel plates or other articles with lead instead of with zinc, or with an alloy of lead and zinc. The process consists essentially in treating the material to be coated in a pickling bath containing about 10 per cent. of hydrochloric acid and 1 per cent. of hydrofluoric acid at a temperature of 120° F., then transferring the articles to a bath of lime-water, and thence to a warm solution of stannous chloride and zinc chloride, and finally to a bath of metallic lead. Electricity is used in the pickling bath, probably to aid in cleansing the metal. The adhesion of the lead to the iron is very considerable, as twisting or bending does not cause the lead to exfoliate. Some tests have shown that the tensile strength of the metal is not reduced by the process.†

* *Engineering Review*, vol. i. pp. 503-504.

† *Engineer*, vol. lxxii. pp. 434-435.

Rust Proof Process.—A method of producing a coating of magnetic oxide on the surface of iron has been devised by M. P. H. Bertrand. The iron is coated first with a metal or alloy by a galvanoplastic method, the coating being such that it is volatilised at a temperature of about 1000° C. The article is then heated in a furnace, and it then, it is stated, becomes covered with a closely adherent layer of magnetic oxide.*

Galvanising in the Cold.—The London Metallurgical Company is introducing a new process of galvanising, which appears to be one in which zinc is deposited from its solution in the cold on the wire or sheets. The inventors claim that in this way a more even and uniform thin coating of the protective metal is obtainable, while at the same time, in the case of wire, the tensile strength is not diminished, as occurs when thin iron or steel wires are galvanised by the common methods of steeping in molten zinc. At the ordinary temperature, too, there is no appreciable tendency to form a zinc iron alloy, which causes a considerable waste of zinc, in addition to the reduction of strength already pointed out, and may be regarded as a further defect in the present system. Comparative tests on the hardness of the coating on sheet iron also show that a plate galvanised by this process has a harder surface than that obtained by the ordinary hot method of galvanising.

An American Tin-Plate Works.—At Demmler Station, M'Keesport, Pennsylvania,† is a tin-plate works with five puddling furnaces, one scrap furnace, a charcoal forge, and two heating furnaces for a muck and sheet bar mill. This latter is a 20-inch mill with the usual equipment of squeezer and shears.

In a line with the bar-mill is a jobbing sheet-mill with 20-inch rolls, 30 inches wide, equipped with a double furnace and driven by a 500 horse-power engine. On the other side of this is a 21 by 37 sheet-mill, on which sheets up to 30 inches wide can be rolled. Then follows a cold-roll mill, with two sets of cold rolls, driven by the same engine.

Next in line is a tin-mill, with 20-inch rolls, 30 inches wide, and one pair of cold rolls, driven by a Corliss engine. Another engine of the same type drives two additional tin-mills recently built in the place formerly occupied by a large sheet-mill.

* *Engineering and Mining Journal*, vol. lii. p. 588.

† *Iron Age*, vol. xlviii. p. 1166.

For the new plant an iron building is being erected with two 87-foot spans 175 feet long. The new plant will be driven by a 36 by 48 engine, equipped with a 25-ton fly-wheel, to be run at 70 revolutions per minute. On the fly-wheel shaft will be a 7-foot 4-inch gear wheel driving a 14-foot 9-inch wheel, from which the trains on either side of the engine will be driven. These trains include two sets of cold rolls 18 inches in diameter and 26 inches wide, and two stands of finishing rolls 20 inches in diameter by 30 inches wide, with a set of roughing rolls between them. On the other side of the engine the sheet-mill removed from the older part of the works will be re-erected. It consists of two stands of 22-inch rolls, 54 inches wide, and room has been reserved for cold rolls for large sizes. There is in contemplation the manufacture of tin-plate 40 inches wide by 108 inches long. Two of the original tinning stacks of the mill have been demolished to make room for these improvements. The annealing is done in a series of five annealing furnaces, and three additional furnaces will shortly be erected.

Six tinning stacks of a type differing considerably from the Welsh one are to be erected. They will be placed side by side in two groups of three stacks each, one group being used for bright plates and the other forterne plates. A very heavy (6 per cent.) coating is to be used, and it is expected that the number of tinning stacks will shortly be increased to 12, each stack having a capacity of three tons per day. The rolling-mill will have a capacity of about 1000 tons a month of light sheets.

Tinning Cast Iron.—All cast iron will not tin well, but some mixtures can be readily tinned if treated in the following way:—Free the article from scale by pickling in a mixture of one-third hydrochloric acid and two-thirds water, quickening its action by a steam-jet, and cleaning away any black spots that may appear. Then wash well, dip in a saturated solution of ammonium chloride, and then into the tin; let them stand in the grease-pot for from five to fifteen minutes, dip them into the re-tinning kettle, and then for a moment again into the grease-pot. To free the finished work from grease use “middlings.” The great point to observe is to carefully free the metal from all scale before it enters the tinning-pot.*

* *Metal Worker*, vol. xxxvii., through the *Iron Age*, vol. xlviii. p. 869.

The Cost of Tin-Plate.—The *Iron Age** publishes a detailed statement relating to a Welsh tin-plate works making 2000 boxes a week, this being the make of four mills, each having a capacity of 500 boxes. The cost of one box of IC plates, 20 inches by 14 inches, is estimated at 2·93 dollars.

The cost of manufacture of 16½ boxes of IC tin-plate in the United States is estimated to bear the following ratio to the cost of manufacture in South Wales, a ton of steel bars being used in each case : †—

	South Wales. Dollars.	United States. Dollars.
Cost of 16½ boxes	49·14	80·92
Cost of one box	2·97	4·90

* Vol. xlviii. p. 1171.

† *Iron Age*, vol. xlviii. p. 1125.

PHYSICAL PROPERTIES.

The Classification of Iron and Steel.—E. Stassano * proposes a rational and systematic classification of iron and steel, based on the chemical composition and physical properties of the material. The classification he suggests is shown in the following tabular summary:—

			Quality.	No.	
CARRIDES	{	(i.) Malleable . . .	Iron .	Puddled .	First . . . 1
				Second . . . 2	
				Third . . . 3	
			Crucible	First . . . 4	
				Second . . . 5	
				Third . . . 6	
		Steel .	Mild .	First . . . 7	
				Second . . . 8	
				Third . . . 9	
			Hard .	First . . . 10	
				Second . . . 11	
				Third . . . 12	
			Extra-hard	First . . . 13	
				Second . . . 14	
				Third . . . 15	
(ii.) Semi-malleable . . .		"Malleable" cast iron	16		
(iii.) Non-malleable . . .		1. Forge pig iron . . .	17		
		2. Spiegeleisen . . .	18		
		3. Foundry pig iron . . .	19		
ALLOYS	{	(i.) Malleable	Nickel steel . . .	20	
			Tungsten steel . . .	21	
			Aluminium steel . . .	22	
			Chromium steel . . .	23	
			Damascene steel . . .	24	
			Ferro-manganese . . .	25	
			Silicon iron . . .	26	
			Aluminium iron . . .	27	
			Chrome iron . . .	28	
			(ii.) Non-malleable		

The Physics of Steel.—The suggestion of Mr. Arnold that recalcence in steel is due to the change from the plastic to the crystalline condition is upheld by Mr. W. Metcalf.† Steel passes through four states—crystalline, plastic, granular, and liquid. If it were not for the granular condition, in which steel has more adhesion than cohesion,

* *Annali della Società degli Ingegneri Italiana*, 1891, p. 9.

† *Engineering*, vol. liii. p. 50.

rolls and hammers could be dispensed with and steel worked by drawing it out. Professor Roberts-Austen, in the curve of cooling obtained by the Alloys Research Committee, shows the point known to steel-makers as "refined," a point that depends on the carbon contents. This point is believed to be coincident with that of recalescence. Below that heat hardening is comparatively slight, but above it there is a great increase in brittleness. Whether this is really so or not might form a field for research in which the effect of various impurities might be included.

This question and the views expressed by Mr. Metcalf are discussed in letters by Mr. Osmond * and Mr. J. O. Arnold.†

Hysteresis.—A long investigation into the laws of hysteresis has been made by Mr. C. P. Steinmetz.‡ The loss due to hysteresis in the magnetisation of iron is directly proportional to the 1·6 power of the magnetisation. The results of a large number of experiments are set out in tabular form, and are also shown as curves to indicate the various relations. Sheet iron, soft steel, cast steel, annealed and hardened steel, cast iron and magnetic iron ore were subjected to various tests, and the results are fully given. For each material there is a constant factor in the equation between hysteresis and magnetisation, and this constant depends less on the chemical constitution of the iron sample than upon its physical condition, annealing decreasing and hardening increasing the hysteresis very considerably. The purer the iron the less is its hysteresis. Manganese increases the loss enormously, wolfram and chromium to a much smaller extent, and silica and carbon least. Connected with increase of hysteresis is always a decrease in magnetic conductivity.

Influence of Temperature on Iron and Steel.—An extended series of researches on the effect of temperature on the strength of various metals has been made by A. Le Chatelier,§ mainly with a view to their use in boiler construction. After dealing with copper and with several brasses, an account is given of the influence on iron and steel. The materials used were Swedish iron, and also soft and extra soft steels of French manufacture. The elastic limit decreases with the rise of temperature, and cannot be estimated above 400°

* *Engineering*, vol. liii. pp. 50, 331.

† *Ibid.*, p. 214.

‡ *Transactions of the American Institute of Electrical Engineers*, vol. ix. pp. 3-64.

§ *Influence de la Temperature sur les Propriétés Mécaniques des Métaux*, Paris, 1891.

to 450° C. The temperatures were attained by using hot air in preference to an oil bath, and were measured by H. Le Chatelier's pyrometer. The breaking load decreased to about 80° C., increased rapidly to a maximum at 250° C., and above 300° to 350° C. it again fell rapidly, until at 400° C. it reached the same amount as at ordinary temperatures. Between 80° and 200° C. the breaking load increased as the rate of its application was diminished, but the converse occurred above 300° C. The elongation suddenly fell at 100° C., though the proportional elongation increased with the speed of loading. Above that temperature the elongation increased. The effect on the contraction of area is shown by the following table:—

Material.	Time of Trial.	Temperature. Centigrade.	Breaking Load.	Elongation.		Reduction of Area.
				Proportional.	Total per Cent. on 5·903 inches.	
	Min. Sec.	Deg.	Lbs.	Per Cent.		Per Cent.
Swedish iron . . .	0 40	140	71·99	7·5	18·2	165
Extra soft St. Cha- mond steel . . .	5 5	140	81·37	5·0	11·1	117
Extra soft St. Etienne steel . . .	0 40	80	70·32	25·0	32·0	206
	2 35	75	77·60	15·0	21·4	153
	0 40	160	84·87	10·0	16·4	192
	4 45	160	94·13	7·5	11·4	129

A curious feature is the way in which the metal elongated. Above 100° C. it became intermittent, proceeding in jerks with a somewhat loud noise, especially in the case of wires. The amplitude increased with the hardness of the metal.

The dangerous period for iron and steel is thus seen to lie between 80° and 250° C. in boiler practice, except in the case of rapid strains or shocks, when it lies between 200° and 400° C. The results obtained at 800° C. show that at that temperature the breaking load decreases rapidly when the length of the trial is prolonged.

Effect of Steam on Magnets.—Some researches of Strouhal and Barus have shown that long-continued heating in steam reduces the power of magnets very considerably. If, however, the magnets are remagnetised, they appear to be less sensible to deterioration after this treatment both from heat and vibration.*

* *Schweizerische Bauzeitung*, through the *Colliery Guardian*, vol. lxiii. p. 710.

Influence of Low Temperature on Iron.—Professor F. Steiner * has experimented on the influence exerted by abnormally low temperatures on weld iron, ingot iron, and cast steel. The test-pieces were in the form of strips 20 centimetres (7·87 inches) long, from 3 to 5 centimetres (1·18 to 1·97 inch) broad, and 7 to 10 millimetres (0·28 to 0·39 inch) thick. Tensile tests gave the following results :—

Description.	Tensile Strength. Lbs. per Sq. Inch.	Elongation Per Cent.	Reduction of Area Per Cent.
Weld iron	3,500	18	20
Ingot iron	3,600	30	60
Cast steel	6,000	4	9

One-half of the specimens submitted to further treatment were nicked at the edge to a depth of 1 millimetre (0·04 inch). The specimens were cooled by liquid carbonic anhydride to temperatures of -40° or -50° for a period of thirty minutes, and then submitted immediately to mechanical tests.

The more important results were as follows :—Each kind of metal, if temporarily cooled down to a very low temperature and then allowed to return slowly to its normal temperature, showed finally no marked change in the results of the bending tests from those of the original sample. Undamaged weld iron, even when at the lowest temperature reached, could be bent 180° ; if it had been nicked this was not possible, the original fibrous fracture having become granular. On the other hand, both the steel and the ingot metal broke sharply when an attempt was made to bend them; their structure was granular. Ice-making machinery should therefore be constructed only of the best weld iron.

The Critical Temperature of Steel.—The *Iron Age* † mentions a number of instances relating to the unreliability of steel when treated at a temperature of about 600° , or at a temperature which would produce a blue colour.

The Influence of Annealing on Wire.—M. Rudeloff ‡ discusses the results of a large series of experiments made with a view to

* *Stahl und Eisen*, vol. xi. p. 1030.

† Vol. xlviii. p. 741.

‡ *Stahl und Eisen*, vol. xii. pp. 63.

ascertain the influence exerted by annealing on wires of various kinds of iron and steel. These included metals of the following composition :—

Metal.	Annealed at Deg. C.	Analysis.					
		C. Combined.	Si.	Mn.	S.	P.	Cu.
Crucible cast steel .	Unannealed	0·46	0·15	0·89	0·01	0·028	0·08
Do. do. .	450—560	0·47	0·13	0·92	0·01	0·029	0·06
Do. do. .	780—880	0·32	0·17	0·96	0·03	0·021	0·05
Ingot iron .	Unannealed	0·15	0·04	1·10	0·03	0·093	0·04
Do. do. .	450—560	0·17	0·03	1·09	0·03	0·095	0·04
Do. do. .	780—880	0·05	0·10	0·95	0·03	0·101	0·05
Ingot iron .	Unannealed	0·02	0·07	0·27	0·05	0·041	0·04
Do. do. .	450—560	0·02	0·07	0·28	0·07	0·039	0·01
Do. do. .	780—880	trace	0·08	0·28	0·07	0·041	0·02

Of each of these samples 44 specimens were taken. The wires, although heated in a lead bath, did not absorb even a trace of that metal. The results are plotted in the form of curves, and they show that heating to a temperature of 475° C. did not affect the tenacity of the wire, and even at 875° no appreciable alteration had taken place in the case of the very soft ingot metal. In the other steels, however, a considerable diminution in the tensile strength resulted on heating to this latter temperature. Similarly the elongation considerably increased. The actual increase in elongation depends on the time the metal is under treatment, but at the end of five minutes the maximum increase in elongation at any temperature has been obtained. The maximum diminution in tensile strength of the crucible steel and higher carbon ingot metal was obtained after heating to 1000°, a still higher temperature having the effect of slightly raising the tenacity again, and diminishing the elongation. The higher the original maximum tenacity the sooner does annealing exert an action on this property. Bending and twisting tests are also recorded.

Experiments made by Professor Paalzou at Berlin on the electro-conductivity of steel showed that with increasing tensile strength the electro-conductivity of the metal diminishes, and that annealing has but little influence in increasing it. An increase in the percentage of carbon greatly diminishes the conductivity of iron. Manganese acts in a similar manner, but the action of silicon appears to be to increase the conductivity. Annealing appeared to show a diminution in the percentage of the carbon contained in the metal, but this diminution

was, as stated, not accompanied by any increase in the electro-conductivity of the annealed metal.

The Texture of Rail Heads.—Dr. H. Wedding* publishes the results of an investigation of the texture of the metal in the heads of steel rails, a number of illustrations of such textures being shown. These illustrations show the existence in the rail head of a more or less central core of a metal differing from that of the external portions of the rail head. Test-pieces were cut from these portions and submitted to mechanical tests. The central portion has a much higher tensile strength than the face, and in some cases the difference between the tensile strength of the metal forming the bearing face of the rail and that of the sides is considerable. The size and shape of the rail influence these results, and, with increasing size, the metal of the rail head becomes more and more unequal and irregular in character, so that a maximum size for the rail must soon be reached. Mechanical treatment greatly affects the character of the rail head. The rail should be submitted to considerable pressure when being finished. This can only be effected by the use, between the horizontal rolls, of rolls with vertical axes to compress the rail head, as is done at the Phoenix Works. By the compression of the rail head, the porous surface portions are done away with. The author describes the method of preparation of the microscope sections used by him in this examination, and the method of obtaining photographic reproductions of the rail surface. With a hard rail the uneven edge caused by the porous character of the material is broken off by the wheels of the trucks passing over it. With very soft rails these protuberances are flattened out and gradually flake off, a true grinding wear of the rail not existing. The rail should, therefore, not be too hard, and its surface metal should be dense and compact.

Basic Bessemer Metal.—The United States Government has issued an order admitting the use of basic Bessemer metal in the construction of the hulls, boilers, and machinery of vessels. The only works in the United States producing this metal is that of the Pottstown Iron Company, Pennsylvania. The results of a large number of tests of the metal produced at this works are now published :†—

* *Stahl und Eisen*, vol. xi. pp. 879-893, with numerous illustrations.

† *Iron Age*, vol. xlviii. p. 842.

BOILER PLATES.

Fire-Box and Flange Quality.

Ultimate Strength.	Elastic Limit.	Elongation in 8 inches.	Reduction of Area.	Phosphorus per Cent.	Sulphur per Cent.
Lbs. per Sq. In.	Lbs. per Sq. In.	Per Cent.	Per Cent.		
52,990	33,050	30·00	66·1	0·025	0·029
53,610	36,190	29·25	74·5	0·030	0·030
57,890	35,450	30·75	66·65	0·025	0·029
57,930	35,570	31·25	59·1	0·025	0·039
55,940	32,860	26·00	53·1	0·025	0·038
57,890	35,450	30·75	65·65	0·025	0·029
57,880	35,140	25·00	67·95	0·030	0·036
57,560	34,320	28·75	64·32	0·036	0·029

Shell Quality.

62,200	36,000	25·0	51·0	0·035	0·039
59,540	35,620	28·0	63·86	0·030	0·032
63,010	39,170	26·0	53·97	0·025	0·029
60,660	35,730	30·50	60·66	0·030	0·04
61,380	38,350	27·50	58·3	0·025	0·03
59,640	37,810	30·0	63·70	0·035	0·029
59,720	36,380	30·0	63·88	0·030	0·030
60,440	34,320	29·50	61·19	0·030	0·030

BRIDGE STEEL.

59,600	35,140	28·25	64·1	0·10	0·06
58,900	35,340	29·50	60·4	0·08	0·02
60,160	38,500	28·75	60·4	0·08	0·05
60,000	35,860	26·50	57·8	0·09	0·06
58,370	35,400	27·50	55·9	0·09	0·04
59,880	34,880	28·75	56·5	0·10	0·03
59,790	34,790	28·25	60·56	0·09	0·06
60,660	35,730	30·50	60·66	0·12	0·03

This bridge steel is Bessemer metal. Only "soft steel" is made at this works.

Testing Machines—A testing machine especially used for testing winding ropes is described by Caillot.* The machine is of the horizontal type. The load is put on by a horizontal hydraulic cylinder which will strain the material up to sixty tons. The device for measuring the stress consists of a lever, the test being attached to the short end, and a cylinder moving in a water tank connected to

* *Société de l'Industrie Minérale, Comptes Rendus*, 1891, pp. 258-261, two plates.

the long end. The diameter of this float is nearly 6 feet, and the lever is of such length that sixty tons is indicated by lifting the float 18.9 inches. This device is, however, very bulky. An automatic registering apparatus controlled by the float and test-piece is used. Coned wedges lined with zinc are used to hold test-pieces of wire cable.

Other illustrations of this machine also appear.*

An account is given by Debray of the Laboratories of the *Ecole Nationale des Ponts et Chaussées*.† This school contains a chemical laboratory, experimental workshop, and a laboratory for testing metals and other materials. By means of plans the disposition of the plant is shown, and tabulated lists of experiments and reports made since 1881 are given.

The laboratory installed by the Eastern Railway of France in their Paris station is described by Oursel.‡ The plant includes a 100-ton and a 25-ton Thomasset testing machine, machine tools, accumulator, and a 20 horse-power engine. Electric transmission of power has replaced line shafting, and has reduced the vibrations which were transmitted to the other offices, and has had several other beneficial results. The dynamo gives 85 amperes at 110 volts. Plans of the laboratory are appended and the testing machine is described.

Testing Iron and Steel.—The subject of the methods of testing iron and steel generally is discussed by Mr. E. C. R. Marks.§ The uselessness of tests for the elastic limit, and the desirability of tests on the finished product are urged. Attention is paid to the methods of chain-testing, and to the qualities of the metal which should be used for its manufacture, and a large part of the paper is devoted to descriptions of testing railway rolling-stock.

Mr. T. Morris,|| in considering engineers' tests of iron, makes some suggestions for standard tests. The requirements of various engineers are criticised at length, and the reduction of area is considered the principal test. The test for the limit of elasticity is held to be of

* *Portefeuille Economique des Machines*, 1892, pp. 45-48, one plate.

† *Laboratoires de l'Ecole Nationale des Ponts et Chaussées*, 4to, plates, Paris, 1891.

‡ *Revue Générale des Chemins de Fer*, vol. xiv. p. 37.

§ Paper read before the Birmingham and Midland Institute of Engineers, November 13, 1891.

|| Paper read before the Liverpool Engineering Society, February 1892, through the *Iron and Steel Trades Journal*, vol. i. p. 309.

no value, and the difference of the strength with and across the grain is pointed out.

Mr. W. E. Koch * considers that in testing steel the test-piece should be always eight inches in length. The present United States one-inch marine test the author describes as absurd and worthless. Tests should be made after any annealing operation; the drifting-test is a good one; cold bends and quench bends are essential, the latter especially so, for all steels with more than 0.18 of carbon; one test per melting heat should be the minimum; the inspection should be done at the mill before shipment; no rejected material should be stamped; and the "coupon" system the author considers to be unfair.

Some experimental notes on elastic tests of iron and steel are given by Mr. J. H. Beare,† from experiments carried out at the engineering laboratory, University College, London. Full details are given with the stress strain curves for tests under tension, compression and tension, and transverse strain. A tabulated statement is given to show the moduli of elasticity derived from the various methods of testing and their ratios. The direct modulus of elasticity in compression is always higher than in tension, but the difference is small in the case of wrought iron and steel, although it becomes as high as 1.16 to 1 in the case of cast iron. In the theory of beams the two moduli are taken as the same, but the divergence in the case of cast iron, although large, is not sufficient to account for the so-called variation of transverse from direct strength. The modulus of all classes of steel and wrought iron has practically the same value, although much working may lower it a little. The ratio of transverse to direct modulus lies between three-eighths and two-fifths.

Cold-Bending Tests with Ingot Iron.—A number of cold-bending tests of basic ingot iron are described by Mehrrens.‡ The results of the original tensile tests of the sixty-four specimens examined showed;—

	Tons per Square Inch.
Limit of elasticity	16.32 to 19.17
Tensile strength	24.82 to 26.73

The elongation varied from 27 to 32 per cent., and the percentage of phosphorus from 0.035 to 0.078; the average of all specimens being:—

* *Iron Age*, vol. xlix. p. 247.

† *Engineering*, vol. lii. pp. 277-278 and 810-811.

‡ *Stahl und Eisen*, vol. xii. pp. 196-198.

Tensile strength, tons per square inch	25.78
Limit of elasticity, tons per square inch	17.59
Elongation, per cent.	28.70
Phosphorus, per cent	0.063

The metal was examined in the form of strips 2.2 to 2.4 inches wide and 0.35 to 0.47 inch thick. These were immersed in freezing mixtures and reduced to temperatures varying down to -95° . A number of experiments are described, and the results show that the quality of the metal was but slightly affected by this treatment.

According to Mehrrens,* pieces of ingot metal were subjected to the action of a freezing mixture for a prolonged period, four or five hours, at the Rothe Erde Works. The temperature of the tests varied from -50° C. to -88° . The results of the subsequent tensile and bending tests showed that the quality of the metal had not been permanently affected even by such prolonged exposure to so low a temperature.

Tests of Round Rolled Bars.—Mr. H. W. Spangler† gives an account of a series of tests upon $\frac{3}{4}$ -inch round rolled iron bars. Ten such bars were taken, and each bar was cut into lengths of about 16 inches. The first set was tested as it was cut from the bar, and averaged 34,545 lbs. elastic limit and 51,097 lbs. ultimate strength. The second set was annealed, and the third set was heated to a welding heat and cooled on the floor. The fourth set was upset to $\frac{15}{16}$ inch diameter by $2\frac{1}{2}$ inches long. The next set had ends welded on. Another set was cut in two and welded together. Part of another set was prepared in the same way and annealed, and the balance of the set was headed. The last set was also headed in the machine on which the upsetting had been done.

The tests show that heating to welding heat and allowing to cool reduced the tenacity 4 per cent., and increased the elongation about 16 per cent. Heating to cherry red and annealing increased the elongation without reducing the average tensile strength. Upset ends are probably as strong as the original bar. The welded pieces had the same elastic limit as the original bar, but were otherwise greatly inferior, the average tensile strength being about 85 per cent. Annealing had no effect. Headed bars, if without flaws, are as strong as the original bars, but 20 per cent. of the heads were defective.

Tests for Cast Steel Wire.—The various tests for cast steel

* *Stahl und Eisen*, vol. xii. p. 220.

† Paper read before the Engineers' Club of Philadelphia, December 19, 1891.

wire are described by M. L. Campredon.* Tensile tests for the ultimate strength, elongation, and elastic limit, the latter especially, are of importance. Bright wire generally shows greater strength and a higher elastic limit than other wire owing to the hard skin. Bending tests are made in a vice with square or, better, with rounded jaws by bending the wire backwards and forwards at right angles to test the softness. Twisting tests for determining the softness are made by looping the wire and twisting it by the loop till it breaks. For determining the efficiency of the galvanising, the wire is bent and subjected for a certain time to the action of a solution of copper sulphate. Some other tests, such as that for malleability, and some of the applications of steel wire are also given.

Testing of Steel Axles.—P. Kreuzpointner † draws the following conclusions :—

1. Steel axles, if carefully made and of the proper grade of steel, are entirely suitable for railway service.

2. Steel for such axles must possess the quality of high resistance to permanent deformation (set), and a sufficient margin of strength and ductility beyond the primitive elastic limit, or limit of proportionality, to leave a necessary safe margin of ductility if the elastic limit should be raised accidentally, which has a tendency to reduce the ductility.

3. The elastic limit of steel axles must be high enough not to be exceeded by the limits of tensile, transverse, or compression stresses of equal strength, acting on a structure alternately, if the structure is to sustain an unlimited number of such stresses. If the elastic limit, or limit of proportionality, is not high enough, fracture in detail will take place.

4. According to Woehler's law on the fatigue of metals, structures or part of structures which have to sustain alternating stresses must have a proportional strength of 9 to 5 in comparison to structures which have to sustain stresses acting only in one direction. Railway waggon axles being subjected to alternating stresses, should have a proportionally high strength.

5. The mechanical treatment of steel car axles must aim at the greatest possible homogeneity, in the sense that the continuity of the structure be not impaired or broken by blowholes, flaws, oxides, or similar defects, as well as in the sense that no variation of structure

* *La Métallurgie; Colliery Guardian*, vol. lxiii. p. 709.

† *Iron Age*, vol. xlviii. pp. 1108-1109.

should exist which would tend to produce internal strains and an irregularly distributed strength.

6. Since the careful annealing of steel tends to eliminate internal strains, and is productive of uniform strength in steel by obliterating the lines of demarcation between portions of a steel structure varying in strength, therefore the annealing of axles must be considered beneficial.

7. Other things being equal, fine "grain" indicates a higher degree of cohesion of the molecules—that is, strength—while at the same time, if the individual particles of the steel are of the proper nature, fine grained steel will flow more easily, will respond more readily to a sudden call for help, and will cushion the blow at the critical moment, thus preventing sudden fracture. Hence a fine grained steel is preferable in axles.

8. The elastic limit should form part of the specifications for steel axles.

9. The drop test is a satisfactory and reliable commercial test for such axles, since it is a measure of uniformity of structure and local weakness, of an excess of softness, and of the ability of the metal to transmit excessive stresses (sudden blows and shocks) quickly from molecule to molecule, thus preventing sudden fracture.

10. The most reliable guide to the selection of proper material for structural purposes in general, and steel axles in particular, is the most intimate knowledge of the physical properties of metals, their behaviour under various conditions, and the effects of heat and work on their qualities and structure.

Breakage of Rails.—An exhaustive report on the breakages of rails which occurred last winter on the Danish railways, especially in Seeland, has appeared. The breakages were partly due to the quality of the rails, and partly to the unfavourable weather. In addition to these causes, the rails were too light for the traffic, speed, and weight of the locomotives, this being more so in Seeland than in Jutland, where the engines are lighter. In future renewals and for new railways, the weight of the rails will be increased, and a closer inspection will be exercised during manufacture. For temporarily strengthening the rails the number of sleepers has been increased, and a large number of fish-plates renewed.*

* *Engineering*, vol. liii. p. 533.

Steel Propeller Shafts.—The photographs of two fractures of steel propeller shafts are given by Mr. H. F. Mais.* The first shaft is $9\frac{1}{2}$ inches in diameter. Near a joint in a brass liner the shaft has corroded under the action of sea-water, and a crack has developed. The shaft was broken at this point, and it is seen that the diameter has been reduced by the crack to practically $6\frac{1}{2}$ inches, and the fracture is crystalline. The fracture is also similar in the second case, while the crack is even deeper.

Testing Boiler Material.—A number of illustrations are published† showing the nature of the mechanical tests to which the metal to be used in the manufacture of Babcock and Wilcox boilers is subjected. They are the ordinary soft metal tests.

The Use of Steel in Bridge Construction.—Professor R. Krohn,‡ in a paper read before the institution of German Engineers at Duisburg, discusses this subject. After referring to previous comparative experiments made between weld iron and ingot metal, the author observes that the prejudice against the use of ingot metal is gradually disappearing, to such an extent, in fact, that in the cases of probably half the bridges which are nowadays erected, the constructor is permitted to use ingot metal. The United States was the first country where this permission was accorded. Softer metal is now being used than was formerly employed, the Russian Government having recently fixed the tensile strength of ingot iron to be used for construction purposes at from 21·6 to 25·4 tons per square inch, with an elongation of 25 per cent. For ship plates the following are the requirements:—

	Tensile Strength.	Elongation.
	Tons per Sq. Inch.	Per Cent.
Bureau Veritas	26·67 to 31·75	20
Lloyds—for boilers	26·00 „ 31·00	20
„ for ships	28·00 „ 32·00	16
German Lloyd	26·00 „ 31·00	20

Basic metal has come rapidly into use, and which of the two materials is the better—basic Bessemer or basic open-hearth—is a matter worthy of consideration. From the very nature of the process

* *Engineering*, vol. lii. p. 575.

† *Iron Age*, vol. xlviii. p. 867, eight illustrations.

‡ *Stahl und Eisen*, vol. xi. pp. 804–818.

it is evident, however, that the former cannot be so uniform in quality as the latter metal. As to the latter, the author publishes the results of a large number of experiments made with a view to show the applicability of this metal for construction purposes. These tests included the mechanical tests of bars in their original condition, of others with holes punched or drilled through them or otherwise treated, and bending tests of joists and other sections.

Other experiments were made to show the deleterious effect of a blue heat, weld iron suffering equally with ingot metal by treatment at this temperature, and, in fact, even more so. The elongation is largely diminished by such prior treatment. The author concludes that for bridge construction the most suitable material is basic metal made in the open hearth and having an ultimate tensile strength of 23.5 to 27.9 tons per square inch. The chief question is in considering the applicability of a metal for such construction purposes, that tenacity is not the main point, but rather to what extent the metal will stand mechanical treatment. Although for compression members a slightly harder metal is permissible than for tension members, too sharp a line of demarcation between the two is not advisable. Rolling into joists or sheets has the effect of diminishing the power of the metal of elongating when under stress, as the author shows by experimental results. Rolling at a low temperature yields a better product than that made at the ordinary temperature. As rolling may and does affect the quality of the metal, test-pieces should be taken and examined after such treatment. The author thinks that the permissible load for ingot iron for bridge members for live loads should be raised to 5.6 tons, and for dead loads to nearly 8 tons per square inch.

The use of steel for bridge construction is also dealt with by F. Bischoff,* in the report of a committee appointed by the Austrian Society of Engineers and Architects to consider the question. An extensive series of experiments were carried out on three classes of materials, namely, wrought iron and mild steel made by the basic Bessemer and by the basic open-hearth process. The experiments were made on girders built up to represent actual working conditions. The various results are fully given, showing the effect of different methods of working. The general conclusion is that the metal should have a tensile strength between 22.2 and 28.6 tons per square inch, with a minimum elongation of 20 to 25 per cent. For good open-hearth steel the suggested composition is not to exceed :—

* *Zeitschrift des Österreichischen Ingenieur und Architekten Vereins*, 1891, p. 63.

Silicon.	Manganese.	Phosphorus.	Sulphur.	Copper.	Carbon.
0·03	0·40	0·07	0·04	0·10	0·16

Plates showing the details of the testing apparatus, the construction of the girders, diagrams of the results, and illustrations of the fractures are appended, and also appendixes containing the mathematical calculations and chemical analyses.

The report of a committee appointed by the Aix-la-Chapelle section of the Society of German Engineers, which has recently appeared,* states that soft steel is to be preferred as a general rule for building purposes. For ordinary purposes, tensile strength should range between 23·45 and 28·60 tons per square inch, with an elongation of 20 per cent. on 8 inches. For bridge-work, the tensile strength should be 23·45 to 27·30 tons. Chemical composition should not be specified, as physical properties are a sufficient indication of the properties of the metal. Blue heat must be avoided in the working. The working load should certainly be increased to 6·35 tons per square inch for live loads and 7·62 tons for dead loads.

A. Martens † discusses at length the recent reports on the adaptability of mild steel as a structural material, as well as the researches of older authorities. The results recently given are tabulated and put into diagram form.

A French commission appointed to revise the former requirements in the case of metal to be used for bridge construction, has decided that no portion of metal in a bridge shall be subjected to strains exceeding the following :—

	Tons per Square Inch.
Cast iron, tensile stress	0·95
Cast iron, bending stress	1·59
Cast iron, compression	3·81
Weld iron, tensile or compressive stress	4·13
Ingot iron, tensile or compressive stress	5·40

If the metal is to be subjected to alternating tension and compression, then these stresses, whether tension or compression, shall not exceed in the case of weld iron 2·54 tons per square inch, nor 3·81 tons in the case of ingot iron. For such metal as is to be used for portions of the road below the rails, these stresses may reach 3·49 tons in the case of weld iron and 4·76 tons in that of ingot iron.‡

C. Stöckl§ observes that bridges began to be made of iron about

* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xxxvi. p. 280.

† *Ibid.*, vol. xxxvi. pp. 172, 204, 236.

‡ *Stahl und Eisen*, vol. xii. p. 119.

§ *Ibid.*, vol. xii. pp. 20-26.

sixty years ago. In Austria the construction adopted was faulty, and bridges breaking down, led to considerable structural changes, the nature of which the author considers. New kinds of metal have gradually come into use, especially open-hearth ingot metal, the use of which has given great satisfaction. One of the most recently constructed bridges made of this material is the Moklau bridge near Budweis, with a span of over 200 feet.

Professor F. Steiner * also discusses bridge construction and the use of aluminium in alloy with iron. Special reference is made to the effect of vibration on the structure. The Bohemian experiments referred to above are discussed, and further experiments made by the author on the same material and on aluminium steel are given. The results obtained from the latter material were:—

Temperature.	Tensile Strength.	Elongation on 8 inches.	Contraction of Area.
	Tons per Sq. Inch.	Per Cent.	Per Cent.
- 60° F.	29·7	22	64·7
+ 43° F.	27·7	26	66·5

Injury to the surface reduced the strength more at low than at ordinary temperatures, but the use of low temperature experiments is questioned. Aluminium has given promising results in improving the quality of steel ingots.

A specification for first-class bridge superstructure is given by Mr. F. H. Lewis,† who discusses at length the use of soft steel as compared with other materials, especially wrought iron. Wrought iron is being used for short spans and medium steel for long spans, but soft steel finds very little use. Wrought iron does not appear to be improving in quality, and soft steel has in some cases been used on an equal footing to replace it, but only to a small extent, as it is somewhat more costly when the working is considered. If it were placed in an intermediate position between medium steel and wrought iron, it might be more extensively employed. A large number of tests are given by the author, and they show that steel is very uniformly less injured by punching than iron. The injury increases with the thickness of the plate, but decreases very much more rapidly with its softness. Soft

* *Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins*, 1892, pp. 113, 149,

† *Proceedings of the Engineers' Club of Philadelphia*, vol. ix. pp. 21-81.

steel in small sections can be made perfectly uniform, but its use in larger ones is limited to compression members, to girders, and to riveted tension members. Some tests of eye-bars are also given.

In the specification the quality of the three materials are dealt with. Soft steel may be employed, but it must be used consistently throughout the work; it must not be welded, and it must not be punched when the thickness exceeds half an inch, except for special work, when it may be $\frac{3}{4}$ inch in thickness. The elastic limit should be 32,000 lbs., the ultimate strength 54,000 to 62,000 lbs. per square inch, with an elongation of at least 25 per cent. in 8 inches and a reduction of area of 45 per cent., except for web plates, when it may be somewhat less. It should close down on bending without cracking. Tests for punched holes are also given.

Tests and Requirements of Structural Wrought Iron and Steel.—Mr. A. E. Hunt* discusses at some length the tests and requirements of structural wrought iron and steel, especially with regard to the following points:—What tests are usually made to determine the quality of structural material; the number of tests required; in what cases more than one test should be made or allowed before decision is reached; the way in which tests should be made; the interpretation of the tests and test requirements; what material the tests should cover; the jurisdiction of the inspector over rejected material; the right and duty of the inspector to note and report upon methods of manufacture. Of the tests used, the tensile test is most frequently employed, but might be replaced in part by cheaper methods, and is advantageously used also on annealed specimens. The drifting test should be a standard test. Bending and nicked bending tests give results depending greatly on the manipulation. Hardening or quenching tests are in the author's opinion of doubtful utility. The bulging test of Kirkaldy is specially adapted for mild steels. Compression tests are not used for wrought iron or steel. Hot and cold forging tests depend on the skill of the manipulator, but the welding test is sometimes useful. The determination of specific gravity and of the chemical composition is also dealt with, the latter being taken in conjunction with physical tests. No definite rule can be laid down for the number of tests, but each melt or each lot prepared in any particular manner should be tested. A second test may be allowed

* *Transactions of the American Institute of Mining Engineers*, Glen Summit meeting (advance proof).

if the first obviously did not represent a fair sample. The tests and the interpretation of the requirements should be fairly made. Both rejected and accepted material should be marked, and if the inspector can report on the method of manufacture, the test requirements may be lessened.

In the course of the discussion on this paper, Mr. W. H. Morris thought that the manufacturers' tests might be accepted, that a standard size of test-piece should be adopted, that the specification should be simple, and should allow a good margin. The necessity for homogeneity in the metal was pointed out by Mr. C. B. Dudley, and also the fact that the margin for tensile tests must be considerably limited, or another class of steel will be supplied which is of no use for the purpose to which it is to be put. The beneficial effect of inspection was illustrated by Mr. E. B. Coxe by reference to the inspection of anthracite.

Armour-Plate Trials.—A trial of a solid steel armour-plate was made on board the *Nettle* in December 1891. The plate was 8 by 6 feet, and $10\frac{1}{2}$ inches in thickness. Five rounds from a 6-inch breech-loader, with charges of 48 lbs. of powder, were fired, Holtzer steel projectiles and Palliser chilled shot of 100 lbs. being used. The plate was uncracked, but the chilled shot and one of the steel projectiles were broken up.*

At Sevran Livry in January experiments were made to test the strength of various descriptions of armour-plate. Six plates of hardened steel, 2·835 inches in thickness, served successively as targets for quick-firing guns of 2·559 inches calibre, throwing howitzer shells with a velocity of 1160 feet per second. Three of the plates manufactured at the Creusot Works and the Marrel Foundry were not cracked after five shells had been fired. Further experiments will be made with these plates.†

Armour-plate tests were made at Indian Head, on October 31 last, with a low-carbon nickel-steel plate made by Carnegie, Phipps, & Co., a high-carbon nickel-steel plate and a low-carbon Harvey process steel plate, both of the latter being made by the Bethlehem Iron Company. Each plate was $10\frac{1}{2}$ inches thick. The gun used for the first twelve shots was a 40 calibre 6-inch breech-loading rifle, and for the next three shots an 8-inch gun was used.

Further trials took place at Indian Head on November 14 of nickel-

* *Iron*, vol. xxxviii. pp. 534-535.

† *Industries*, vol. xii. p. 126.

steel armour-plates, containing 0·40, 0·25, and 0·35 per cent. of carbon respectively. The two latter plates were treated by the Harvey process. Similar guns to those employed at the last trial were used. In both the treated plates there was evidently a lack of uniformity in the tempering.

On January 13 two other plates were tested. They were both made by Carnegie, Phipps, & Co., and were treated by the Harvey process. Neither of the plates had quite the proper dimensions, so that the results obtained could not well be compared with those from previous trials. The tests, however, demonstrated the value of nickel-steel plates treated by the Harvey process.

These trials of American-made plates on October 31 and November 14 are described by Lieutenant J. M. Califf.* Illustrations are given to show the behaviour of the plates, and the results of the various shots are set out in tabular form, showing the penetration and the effect on the projectile and on the plate.

The official report of the United States Board of Armour Tests has been issued. It states that the best results were obtained with the high-carbon nickel-steel Harvey plate furnished by the Bethlehem Iron Company. The second best plate was a high-carbon nickel-steel plate un-Harveyised, furnished by the same Company, and the third a rolled high-carbon nickel-steel plate of Carnegie, Phipps, & Co. Low-carbon metal gave bad results, whether nickel-steel or ordinary steel.

Steel as applied to armour is discussed by Lieutenant J. H. Mansell, who advocates a hardened-faced plate with backing of softer metal.† The various recent trials are considered and the results compared.

In the course of an exhaustive paper on the progress of the metallurgy of nickel, D. Levat ‡ discusses the application of nickel-steel to armour-plates, giving details of the results of the trials made at Annapolis in October 1890, at Indian Head on November 14, 1891, and at Gavre in July 1891.

An illustrated account of the various recent armour trials is given by Captain Orde Brown in the *Naval Annual* § for 1892.

* *Railroad and Engineering Journal*, vol. lxvi. pp. 34-36.

† *Proceedings of the Royal Artillery Institution*, vol. xix. pp. 227-234.

‡ *Annales des Mines*, 9th Series, vol. i. pp. 141-226.

§ Pp. 291-301.

CHEMICAL PROPERTIES.

Rusting of Iron.—Professor A. Liversidge* points out that, although it was usually stated that iron rust consisted of the hydrated ferric oxide, he found on examining a large number of specimens that in almost every instance the rust contained more or less magnetic oxide. In fact, in some cases the rust was when powdered practically wholly attracted by the magnet. The specimens which first attracted his attention were some large scales of rust from the rails of an old tramway at Clifden Springs in Victoria, and he was led to examine these on account of their resemblance to the crust so often present on metallic meteorites. Bright iron wire, plates, rods, and nails were artificially rusted in many ways with free access of oxygen, and in almost every instance a large amount of magnetic oxide was formed.†

Action of Carbonic Oxide on Iron.—M. Guntz‡ has repeated the experiments made by various investigators, and finds that iron absorbs carbonic oxide at a dull red heat, carbon being set free, and a small quantity of carbonic anhydride formed. The formation of carbonic anhydride and also that of ferrous oxide, as observed by Schützenberger, may be explained by the known reducibility of ferrous oxide by carbonic oxide, if it is assumed that the action of the metal itself on the monoxide resembles that of manganese. The monoxide is thus first reduced to carbon, and the ferrous oxide formed is then reduced to iron by a further quantity of the gas. At very high temperatures the reaction of carbonic oxide with iron is reversed, the metallic oxide being easily reducible by carbon, with the formation of carbonic oxide.

A résumé of the recent contributions on the subject of volatile compounds of metals, especially nickel and iron with carbonic oxide, is

* Paper read before the Australasian Association for the Advancement of Science; *Nature*, vol. xlv. p. 424.

† Compare *Journal of the Iron and Steel Institute*, 1888, No. II. p. 129.

‡ *Comptes Rendus de l'Académie des Sciences*, vol. cxiv. pp. 115–117.

given by Mr. C. F. Townsend.* Especial attention is paid to the researches of Guntz on the action of this gas on iron and manganese. The discovery of these carbonyl series of compounds already gives a clue to the action of the cementation process in which the carbon permeates the iron when the two are heated together.

Analysis of an Indian Dowel.—In the report on the analyses of various examples of Oriental metal-work in the South Kensington Museum, made under the direction of Professor W. C. Roberts-Austen by Mr. A. Wingham,† there is given the results of an analysis of an iron dowel from the stone-work of a temple destroyed by Altomash, A.D. 1211–1236. The iron is practically pure, containing as it does but 0·20 per cent. of silica and a trace of carbon. It contains no manganese and no phosphorus. The dowel, however, contains 0·44 per cent. of slag, visible on the surface, etched with perchloride of mercury, which had not been eliminated in working.

A Persian steel bowl and a Persian chased steel bottle of the nineteenth century gave on analysis 0·94 and 0·92 per cent. of carbon respectively. They are thus high-carbon steels, as rich in carbon as some tool-steels. They are very hard, and a great amount of time must have been spent in working them.

The Alloys of Iron and Tungsten.—M. J. B. Nau ‡ discusses these alloys, and refers to the investigation of their properties made sixteen years ago by Professor Åkermann. These results were published in pamphlet form, and from this pamphlet the writer draws much of the information he gives. Tungsten steel must be given its final shape by hammering when at a red heat, and even then, if the percentage of tungsten is high, it must be treated very carefully. When cold, the only operation to which it can be submitted is grinding. When, after hammering hot and repeated reheatings, the desired shape has been attained, the hammering must still be continued gently and with numerous blows until it becomes nearly cold. Then only can it be cooled entirely. Further details relating to these alloys were given in the last volume of the *Journal of the Iron and Steel Institute*. §

Steel for Cutting Tools.—Mr. J. C. Moorhouse || describes the

* *Engineering*, vol. liii. pp. 340–341.

† Report on the Analysis of Various Examples of Oriental Work in the South Kensington Museum, 1892, p. 35. ‡ *Iron Age*, vol. xlix. p. 248. § 1891, No. II. p. 309.

|| Paper read before the Leeds Association of Engineers, November 1891, through the *Colliery Guardian*, vol. lxii. p. 1070.

manufacture of steel suitable for cutting tools, and classifies them as follows according to their carbon contents:—For turning, planing, and drilling, $1\frac{1}{2}$ per cent. ; for turning, planing, and slotting, and for small cutting tools, $1\frac{1}{4}$ per cent. ; for milling cutters, mill picks, taps, and rimers, $1\frac{1}{2}$ per cent. ; for cold chisels and shear blades, 1 per cent. ; for forging dies, swages, and fullers, $\frac{2}{3}$ per cent. ; for hammers, snaps, and miners' drills, $\frac{3}{4}$ per cent. A steel with a soft core is manufactured for taps.

Formation of Blowholes in Steel Castings.—A theory of the formation of blowholes in steel castings is proposed by M. Le Berrier,* according to whom a bath of molten steel is a supersaturated solution of hydrogen and nitrogen. If it solidifies quietly, nothing disturbs the molecular equilibrium ; but if, through secondary reactions, bubbles of some other gas are produced in the bath, the equilibrium is at once destroyed, and the absorbed gases are liberated and give rise to the blowholes.

E. de Billy† considers this question. After discussing the question historically, he proceeds to mention the various theories which have from time to time been suggested to account for the presence of blowholes, giving the following analyses of the gas obtained from metal apparently free from blowholes :—

Hydrogen.	Nitrogen.	Carbonic Oxide.
52.1	44.0	3.9
86.5	9.2	4.3

Hydrogen is always the main constituent of this gas mixture, carbonic oxide being only found in very small quantities. The principal of these theories are those of Müller, who favoured direct absorption and evolution again on the metal cooling, and various reaction theories. Silicon, if present, tends to prevent the absorption of hydrogen, while manganese acts in the inverse manner. The author favourably regards the use of aluminium as an addition to the metal on pouring.

The Spectrum of Iron and the Periodic Law.—In the course of some researches on iron containing—

Carbon.	Sulphur.	Phosphorus.	Manganese.
0.1	0.08	0.070	0.4

Mr. J. Parry‡ noticed that it evolved vapour showing the hydrogen

* *Engineering*, vol. liii. p. 19.

† *Génie Civil*, vol. xx. pp. 126-129.

‡ *Nature*, vol. xlv. pp. 253-255.

spectrum when heated *in vacuo*, even at a temperature of 70° to 80° C. On heating iron electrodes, three spectra were observed:—(1.) Lowest heat, a nearly pure manganese spectrum; (2.) higher heat, manganese lines, with other long lines and the beginning of a short-line spectrum; (3.) highest heat, a complete iron spectrum. The long lines observed in the second spectrum could not be referred to either iron or manganese, but appear to be a function of the temperature and the partial dissociation of the metal, or at least a modification of its composition.

The researches of Crookes and Lockyer on the dissociation of the elements are referred to, and the probable bearing of them on these experiments. The existence of α and β iron has already been noticed and worked at by Osmond, Professor Roberts-Austen, and Dr. Ball, and the author thinks that the results of their researches go far to prove that the undoubted molecular changes which take place when iron is heated simply represent marked periods of dissociation,—an opinion borne out by all the above-mentioned researches. The physical properties of iron are a function of the temperature. Appreciable dissociation requires wide limits of temperature, but its beginnings may be observed by the spectroscope if carefully worked and used as an aid to analysis in the same way that a microscope is used. Pure iron is probably a very complex body, whilst commercial iron certainly is, as shown by Professor Sorby's microscopic investigations, extremely sensitive to external influences modified by the presence of minute proportions of other bodies. The importance of the atomic value of these latter is shown by Professor Roberts-Austen, and so it should be necessary to give the relative mass as well as the mere percentage to obtain the absolute percentage composition.

From his previous experiences the author is convinced that the temperature plays a very important part in the manipulation of steel, and instances a case in which two steels with very different strengths had identically the same composition. Some clue to the proper temperature for working steel may perhaps be obtained from its melting-point, which may be taken at a certain distance above the welding or rolling temperature. Deviations from this temperature may often be accountable for the variations in the quality of the steel. The term impurity, as applied to other elements in iron, is simply a conventional one, applicable only under certain rigid conditions of temperature combined with manipulation. Finally, the author quotes Dr. Gore to the effect that every substance becomes a more or less different substance at every different temperature.

CHEMICAL ANALYSIS.

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I.—ANALYSIS OF IRON AND STEEL.

The Determination of Carbon.—A. J. Rossi* describes the various modifications of the colorimetric method, the samples to be tested being compared with various undiluted or diluted standards simultaneously dissolved.

Reference is also made to Lezé's method of volumetric analysis when precipitates are formed, the solution being whirled in a centrifugal apparatus, causing the precipitate to settle clear from the supernatant liquor. A number of similar bottles being used with an equal quantity of solution and varying quantities of the standard, a further addition of the standard solution to each of the clear solutions after the centrifugal action instantly shows to which of the bottles the right quantity had been added in the first instance.

H. von Jüptner† discusses the Wiborgh gas volumetric method for the determination of carbon in iron and steel.‡ The gas volume should be read at a definite temperature and normal barometric pressure, and the author gives a table for this purpose. Various slight modifications of the process are mentioned, and a very large number of results are given showing the accuracy attainable.

The Determination of Phosphorus.—A rapid process for the determination of phosphorus in iron, steel, and ores is described by

* *Stahl und Eisen*, vol. xi. p. 928.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. pp. 534-537.

‡ *Journal of the Iron and Steel Institute*, vol. 1887, No. II. p. 359.

Mr. J. O. Handy.* This method consists of the following points:—
 (a.) Separation of the phosphorus as pure phospho-molybdate of ammonium, by washing with neutral potassium nitrate solution, after the regular washing with 1 per cent. nitric acid. (b.) Solution of the pure phospho-molybdate in a measured volume of a standard sodium hydrate solution. A definite quantity of the alkali is taken up in neutralising the phospho-molybdate. (c.) Titration of the excess of sodium hydrate by means of standard nitric acid. Phenolphthalein is used as the indicator. The end reaction is very distinct. Duplicate analyses have given closely concordant results, which agree exactly with determinations of phosphorus by gravimetric methods. Without any special appliances, and without the use of suction, analysis can easily be done in thirty minutes, but it is believed that this time can be shortened one-half. An analysis has, in fact, just been done in seventeen minutes. The author states that he has confirmed by long experience Dr. Drown's statement that sugar can be safely used as a reducing agent in the process. Mr. Clemens Jones substitutes ferrous sulphate, but the author finds that it requires several times as much ferrous sulphate as sugar for reduction, and that the sugar produces no ill effects. The paper closes with a table of results of some of the experiments by which the accuracy of the method was established, the comparison being between results obtained by weighing and by titrating the phospho-molybdate. A committee was appointed to investigate the method and report results at the next meeting.

H. Wdowiszewski† dissolves the steel to be assayed in nitric acid, boils, adds some permanganate solution, and boils until the precipitated manganese peroxide settles readily. A little hydrochloric acid is then added, dissolving the manganese, the solution being heated until all the chlorine has escaped. The solution is then over-neutralised with ammonia, the iron hydrate dissolved in nitric acid, and the phosphorus precipitated in the usual way with molybdate. The precipitate is dissolved with a standard ammonia solution and the excess of ammonia titrated back with hydrochloric acid.

The volumetric method,‡ in which the molybdate precipitate is dissolved in a known quantity of very dilute ammonia, and the excess of ammonia so employed titrated back by a standard solution of dilute

* Paper read before the Chemical Section of the Engineers' Society of Western Pennsylvania, March 24, 1892.

† *Stahl und Eisen*, vol. xii. p. 381.

‡ *Journal of the Iron and Steel Institute*, 1891, No. I. p. 435.
1892.—i.

sulphuric acid, is stated to be due to E. Thilo, and to be generally applicable.*

C. Malot † precipitates the phosphorus in iron solutions in the usual way with molybdate, and then dissolves and reprecipitates with magnesia mixture. The magnesia precipitate is dissolved off the filter paper with nitric acid of 1.2 specific gravity, and the phosphoric acid precipitated by the aid of a solution of uranium nitrate, the end of the reaction being readily observable owing to an excess of uranium oxide giving a green colour with cochineal tincture. To the phosphorus solution, therefore, a few drops of cochineal solution are added, this solution being obtained by dissolving in boiling water. Ammonia is then added carefully until a lasting violet colour is obtained, which is then removed by a few drops of nitric acid. Five cubic centimetres of a 10 per cent. solution, and 50 of glacial acetic acid are then added, the whole solution raised to the boiling-point, and the hot solution titrated with a standard solution of uranium nitrate, each drop of which causes a blue-green precipitate. This precipitate disappears on stirring as long as any phosphoric acid remains in the solution; but when this has been completely precipitated, the next following drop of the uranium solution turns the red colour due to the cochineal into that of this green uranium compound, which now no longer disappears on stirring. Any further addition of the uranium solution is without any action on this green compound.

Mr. R. Hamilton ‡ refers to the deleterious influence exerted by the presence of carbonaceous matter in the solution on the results obtained by the molybdate method for the determination of phosphorus. In Dr. Drown's modification of the method proposed by Shimer, the iron is dissolved in dilute nitric acid, the phosphorus precipitated direct, and the precipitate dissolved and the phosphorus reprecipitated with magnesia mixture, or, if in too small a quantity for that, reduced with zinc and titrated with standard permanganate. The author has examined this method. His preliminary experiments, made on a pig iron containing some $2\frac{1}{2}$ per cent. of combined carbon, showed that the presence of carbonaceous matter in the solution containing the phosphorus in the form of phosphoric acid, did not prevent the precipitation of the phosphorus with molybdate. The author next examined the question whether the phosphorus in iron can be rendered completely

* *Chemiker Zeitung*, vol. xv. p. 657.

† *Zeitschrift für Analytische Chemie*, vol. xxxi. pp. 78-79.

‡ *Journal of the Society of Chemical Industry*, vol. x. pp. 904-906.

precipitable by oxidation while in solution. Using as an oxidising agent hydrogen peroxide in a nitric acid solution, the carbon solution colour was destroyed, and 95 per cent. of the phosphorus afterwards precipitated. A larger addition of the hydrogen peroxide increased this percentage of precipitated phosphorus to 99.3, and the joint use of permanganate and the hydrogen peroxide 99.7 per cent. A number of other experiments in this connection were made; and the author, in his concluding remarks, observes that his experiments showed:—(1.) That the carbonaceous matter in a solution of iron does not prevent the complete precipitation of properly oxidised phosphorus as ammonio-phospho-molybdate. (2.) That the reason of the incomplete precipitation of phosphorus from a nitric acid solution of iron, which has not been evaporated to dryness and roasted, is that the phosphorus has not all been properly oxidised. And (3.) that in such solutions all the phosphorus can be completely oxidised and rendered precipitable in the wet way by means of certain oxidising agents.

According to Crispo * the quantity of the molybdate precipitate is not a constant one, but is dependent on the quantities of phosphoric, molybdic, and nitric acids present. The composition of the precipitate is not a constant one, and in order to obtain successful results the approximate percentage of phosphorus should be known beforehand. The author considers that the method, in its simplest form, should be abandoned.

The Determination of Manganese.—Referring to the criticisms on their labours published by Hampe† and by Donath,‡ the Committee of the Association of German Ironworkers that examined this question state§ that of forty-five works it was found that nineteen were using the Wolff permanganate method. Samples of various manganiferous materials were distributed among a number of chemists, and the results these obtained with volumetric methods agreed well with those of gravimetric methods when the percentages of manganese were low, but not when these were high. It was then decided to confine the examination to one material, ferromanganese, and two recognised authorities were chosen in the first instance to determine the percentage of manganese the ferromanganese contained. Those chosen were Professors Fresenius and Hampe. These found respectively

* *Bulletin de l'Association Chimique Belge*, vol. v. pp. 201-216.

† *Chemiker Zeitung*, vol. xv. p. 1579, and vol. xvi. No. 2.

‡ *Ibid.*, vol. xvi. p. 141.

§ *Stahl und Eisen*, vol. xii. pp. 290-292.

76·04 per cent. and 78·34 per cent. The other members of the Committee, using the permanganate method, found from 76·5 to 77·13 per cent., and those using the chlorate method 75·14 to 76·04 per cent. The average of several analyses of the other elements present showed—

C.	Fe.	Si.	Cu.	Ni+Co.	P.	S.
6·966	16·04	0·27	0·023	0·175	0·245	0·015

The manganese by difference is thus 76·272. A later analysis made at another steelworks showed 76·4 per cent. of manganese.

Professor Fresenius adopted the gravimetric method, precipitating the manganese as sulphide, and testing the filtrate with bromine and ammonia—the method described by him in his *Chemische Analyse*, vol. ii. p. 437. Professor Hampe, on the other hand, whose results differed so widely from those of the other members of the Committee, employed in the first place the Hampe chlorate method, but the results being found to differ more than was usually the case, it was concluded that the sample was of irregular composition, and the remainder was therefore dissolved and determined by the sodium acetate method, precipitating three times, the latter result being taken as accurate. The Committee severely criticise Professor Hampe's results. The sample as sent to the various chemists left no residue when passed through a sieve of 230 meshes to the linear inch—a mesh 0·0043-inch in diameter—the normal sieve for slag-meal. The sample was carefully prepared, and the mode of preparation is described.

M. A. von Reis * discusses the chlorate method for the determination of manganese. He observes that this method when performed in the way described by Hampe is of no use in an ironworks laboratory, but that it is when using the Ukena method. Then, there is no bumping on boiling and the solutions after the chlorate addition can be left to themselves, and the solutions of chlorine compounds is reduced to a minimum. Professor Finkener considers the chlorate method, however performed, to be an inaccurate one.

According to C. Vortmann,† the electrolytic determination of manganese becomes possible by the addition of mercury, into which the manganese passes, forming an amalgam. The author does not use metallic mercury, but a solution of mercuric chloride, or in acid solutions pure mercuric oxide. By the simultaneous precipitation of the mercury and the manganese the amalgam is much more uniform than

* *Chemiker Zeitung*, vol. xv. p. 1791.

† *Berichte der Deutschen chemischen Gesellschaft*, vol. xxiv. p. 2749.

is otherwise the case. Mercury seems easy to precipitate electrolytically from all its solutions. The amalgams are washed with water then with alcohol, and finally with ether, and dried by blowing while holding the dish containing the mercury in the hand. It is then placed in the dessicator and weighed. A number of metals which do not form coherent metallic deposits can be determined in this way, such as zinc, lead, cadmium, arsenic, antimony, and bismuth.

A. J. Rossi * describes the colorimetric method as follows:—0.0695 gramme of manganese sesquioxide is dissolved in hydrochloric acid and evaporated to dryness. There is then poured over the residue 10 cubic centimetres of nitric acid of 24° B. and 100 cubic centimetres of a 10 per cent. solution of sodium metaphosphate. The solution being continually stirred, 15 grammes of finely-powdered calcium carbonate is gradually added, and the solution diluted to half a litre. One cubic centimetre of this solution equals 0.0001 of manganese; with the filtered solution a number of tubes are filled, the solution being so diluted as to form a colour scale of such a character that 0.25 gramme of the substance to be assayed may contain from 0.01 per cent. to 2 per cent. of manganese. In the case of iron, 0.25 gramme is taken, dissolved in 3 or 4 cubic centimetres of hydrochloric acid and evaporated to dryness; a few cubic centimetres of dilute nitric acid and thirty of the metaphosphate solution are then added, and two grammes of calcium carbonate gradually stirred in. As soon as, on continued stirring, an evolution of chlorine becomes observable, the solution is filtered into a graduated tube and diluted to 50 cubic centimetres and then compared with the colour scale. The author also describes the Pattinson volumetric method. This latter will be found in detail in Fresenius' *Anleitung zur Chemischen Analyse*, 6th edition, vol. ii. p. 440. The author also describes the ordinary methods for the determination of sulphur.

The Determination of Iron and Silicon in Commercial Aluminium.—For this purpose the metal should be dissolved in a solution of potassium hydrate. The solution, in the case of the determination of silicon, is then neutralised with hydrochloric acid, evaporated, and the silica determined in the usual manner. For the determination of iron in the alkaline solution, this is acidulated with sulphuric acid, the solution being boiled until quite clear. All the iron is present in the ferrous form, and may be titrated at once with permanganate.

* *Stahl und Eisen*, vol. xi. p. 927.

If the aluminium itself is to be determined, the alumina is precipitated by boiling with ammonium nitrate. It is then dried and weighed, a portion being extracted with water for the determination of alkali precipitated with the alumina, and another portion fused with potassium bisulphate, the fused mass extracted by water, and the silica, which had also been precipitated with the alumina, determined in this manner.*

II.—ANALYSIS OF IRON ORES—SLAG.

The Volumetric Determination of Iron.—R. Namias † considers the ordinary method of estimating iron by bichromate, using potassium ferricyanide as an indicator, to be somewhat inaccurate. He finds the following method to give good results:—An excess of standard bichromate solution is run into the solution of the ferrous salt, acidified with hydrochloric acid, a few drops of iodine and starch solution are added, and the excess of bichromate determined by titration with standard stannous chloride solution.

The Determination of Iron and Alumina in the Presence of Phosphoric Acid.—Mr. W. H. Krug ‡ has examined several methods of such analysis, and finds that of M'Elroy to be far the best. This consists in first precipitating the phosphorus by molybdate solution, filtering through a dried filter, adding a little ammonium nitrate to the solution, and then precipitating the iron and alumina by the careful addition of ammonia, redissolving and again precipitating, fusing with sodium bisulphate, dissolving in water, and determining the iron in the usual way.

Decomposition of Chrome Iron Ore.—P. Jannasch and H. Vogtherr § state that the method for decomposing silicates by heating with hydrochloric acid under pressure may advantageously be adopted for the decomposition of chrome iron ore for quantitative analysis. The most suitable acid is a mixture of four volumes of concentrated hydrochloric acid of sp. gr. 1.119 with one volume of water. It should be

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 570.

† *Gazzetta chimica italiana*, vol. xxi. pp. 473-476.

‡ *Journal for Analytical and Applied Chemistry*, vol. v. p. 671.

§ *Berichte der Deutschen chemischen Gesellschaft*, vol. xxiv. pp. 3206-3208.

saturated with ammonium chloride. The tubes must be heated for about ten hours at 250° C., the decomposition being then as complete as with the methods usually adopted.

Determination of the Value of Chrome Iron Ore.—C. Halussermann * discusses the determination of the value of chrome iron ore, especially as regards its use for the manufacture of bichromate. The method adopted is as follows:—

Dry and determine the moisture. Then fuse 0.5 gramme with four grammes of a mixture of three parts potassium carbonate and one of caustic soda for two hours in a platinum crucible. After cooling, dissolve out with water, dilute to one litre, and add excess of sulphuric acid. If a sandy residue remains undissolved, this is a proof that the ore was not sufficiently finely powdered before being fused. In the acid solution, the chromic acid is determined in the usual manner by the aid of a standard solution of ferrous sulphate. Both platinum crucibles and silver crucibles are rapidly attacked by the fusion necessary in this method of analysis.

The Determination of Manganese.—P. Jannasch and C. J. Franzek † discuss the separation of manganese from nickel and cobalt by the aid of hydrogen peroxide. In a strong ammoniacal solution, much ammonium chloride being present, no nickel passes into the hydrate of the manganese peroxide produced, but if cobalt is present a considerable percentage is precipitated. From a solution of the sulphates, converted into the form of a double cyanide with potassium, the manganese is precipitated by hydrogen peroxide quite free from cobalt or from nickel.

The Determination of Phosphoric Anhydride in Slags.—Mr. V. Edwards ‡ decomposes the slag by boiling with sulphuric acid, taking 0.5 gramme for the analysis. The phosphoric acid in the diluted and filtered solution is precipitated by the citric magnesia mixture and ammonia. The precipitate is then redissolved in dilute nitric acid, and the phosphorus determined by titration with uranium solution.

The Determination of Sulphur.—G. Craig § determines sulphur in iron slags, &c., by treatment with hydrochloric acid, the sulphuretted

* *Chemiker Zeitung*, vol. xv. p. 1602.

† *Berichte der Deutschen chemischen Gesellschaft*, vol. xxiv. p. 3204.

‡ *Chemical News*, vol. lxiv. p. 275.

§ *Ibid.*, vol. lxiv. p. 266.

hydrogen being passed into ammoniacal hydrogen peroxide, and the sulphuric acid produced being afterwards determined in the usual way. If iron pyrites is being examined, this is, in the first instance, heated with zinc-dust. If not heated for more than a brief period, no sulphates are reduced, but this does occur if the mass is heated strongly for five or ten minutes.

The Determination of Titanium.—Mr. F. P. Dunnington * observes that the determination of small quantities of titanium has been rendered much easier by Weller's method, which is based on the production of an intense yellow-coloured compound by the addition of hydrogen peroxide to the titanium solution. The material to be examined should be fused with sodium hydrogen sulphate and then dissolved in dilute sulphuric acid of at least 5 per cent. strength, and not in water nor in very dilute acid, in either of which cases inaccurate results ensue, owing to the formation of metatitanic acid.

The Determination of Cobalt in Manganese Ores.—Mr. T. Moore † fuses 2 grammes of the ore with 4 or 5 grammes of potassium hydrogen sulphate for fifteen or twenty minutes in a platinum dish, using the highest temperature possible with a Bunsen burner. To the well-fused mass, while it is being heated, a piece of ammonium carbonate is added, a cover being placed on the dish to prevent spitting. The addition of carbonate is repeated until at last the fused mass gives off only slight fumes of sulphuric acid. The fused mass is then poured on to a clean metal plate and allowed to cool. It is then boiled for twenty minutes with about 400 cubic centimetres of water, allowed to settle, filtered, the insoluble residue again boiled with water and filtered as before. This residue consists of basic sulphates and silica, and is quite free from either nickel or cobalt. The filtrate is heated, 30 cubic centimetres of acetic acid are added to it, and then a rapid current of sulphuretted hydrogen passed through it. The last traces of iron reduced, an addition is made of 50 cubic centimetres of a strong solution of ammonium acetate, and then, the solution being kept boiling, the whole of the nickel and cobalt is precipitated. The sulphides rapidly settle, and may readily be filtered. The precipitate is then ignited at as low a temperature as possible, dissolved in hydrochloric acid, converted into a sulphate solution, precipitated

* *Journal of the American Chemical Society*, vol. xiii. p. 210.

† *Chemical News*, vol. lxx. p. 75.

electrolytically, and the nickel and cobalt separated in the usual way.

A second method for the direct determination of cobalt is based on the absorption of oxygen by ammoniacal cobalt solutions. Manganese, it is true, forms a similar ammonia double salt which absorbs oxygen from the air, but in a mixed manganese cobalt solution, if an excess of citric acid is added, and then ammonia, the manganese salt loses the power of oxygen absorption to such an extent that its action may be disregarded. The citric acid, too, prevents the precipitation of either iron or alumina. The absorbed oxygen acts according to the equation $2\text{CoO} + \text{O} = \text{Co}_2\text{O}_3$, equivalent to 1 cubic centimetre of oxygen at 0° and 760° millimetres pressure for each 0.0105 of Co.

In carrying out this method of assay, 2 grammes of the ore are dissolved in hydrochloric acid, the solution evaporated to dryness, and 3 grammes of citric acid dissolved in 3 or 4 cubic centimetres of ammonia is added to the residue. The acid must be in slight excess. If the solution is alkaline, one or two drops of hydrochloric acid must be added until a marked acid reaction is observed. The whole is then heated until the solution is as complete as possible, and if too concentrated, some 2 or 3 cubic centimetres of water is added, the solution being then allowed to cool. The rest of the operation consists in adding ammonia and then observing in a gas absorption apparatus how much oxygen the solution will absorb.

The Determination of Arsenic.—The following method for the determination of small quantities of arsenic in iron ores is given by F. Jean and V. Marchais.* The sample is dissolved in nitro-hydrochloric acid, evaporated to dryness to remove silica, and the residue extracted with hydrochloric acid. To the filtrate ammonia is added, and the precipitated hydrate of iron carries down the phosphorus and arsenic. After washing with boiling water, the precipitate is dissolved in nitric acid and an excess of ammonic molybdate is added to precipitate the phospho- and arsenio-molybdate. This precipitate is filtered off, washed with a 15 per cent. solution of ammonium nitrate, dissolved in a small quantity of ammonia, and again precipitated with magnesia mixture. The precipitate is filtered off, washed with dilute ammonia, and dissolved in hydrochloric acid. The arsenic can then be precipitated from this solution by ammonium sulphide, as sulphide in which the arsenic can be determined by the magnesia mixture process. In some cases it is

* *La Métallurgie*, 1892, pp. 415-416.

possible to precipitate the arsenic and phosphorus direct from the solution of the ore by the molybdate if hydrochloric acid be first driven off by nitric acid.

The Separation of Baryta and Lime.—R. Fresenius * has examined a number of methods for the separation of these bases when simultaneously present. He finds that from weak acetic solutions a complete separation may be effected by the aid of neutral ammonium chromate, precipitating twice. Similarly a perfect separation can be effected with hydro-fluosilicic acid, washing the precipitate with water, adding sulphuric acid to the filtrate, converting the sulphates into chlorides and reprecipitation with the hydro-fluosilicic acid, in the presence of alcohol.

Detection of the Adulteration of Basic Slags.—Dr. Morgen,† before the Agricultural Section of the Congress of Naturalists and Physicians, pointed out the various methods of detecting adulterations in basic slags. There should be no loss on ignition above $\frac{1}{2}$ to 1 per cent. The determination of the specific gravity also gives a clue, and for this purpose the author uses bromoform with a specific gravity of 2.91. "Taffin" slag can thus be separated. A dilute solution of soda lye separates basic slag and Redonda phosphate, and the latter in coarsely-ground samples shows yellow particles. The best method for a quantitative determination is that of Jantsch and Schucht. The P_2O_5 of basic slag is perfectly soluble in a 5 per cent. solution of citric acid.

III.—FUEL ANALYSIS.

The Determination of Sulphur in Coal.—J. Rothe‡ has examined the Eschka method for the determination of sulphur in coal. In this method 1 gramme of coal is fused with a 1.5 gramme of a mixture of two parts magnesia and one part of anhydrous sodium carbonate, the sulphur in which has been determined. For the fusion a platinum crucible of about 30 cubic centimetres capacity is employed. The mass

* *Zeitschrift für analytische Chemie*, vol. xxx. pp. 18, 452, 583.

† *Chemiker Zeitung*, vol. xv. p. 1397.

‡ *Mittheilungen aus des Königlichen technischen Versuchsanstalt*, through *Stahl und Eisen*, vol. xii. p. 31.

is heated gently over a Bunsen burner. In an hour the combustion is complete, after cooling the contents of the crucible are removed into a beaker, moistened with a few cubic centimetres of bromine water, then any remainder of the crucible contents is washed out of the crucible with dilute hydrochloric acid, and added to the main mass in the beaker. When the whole of the basic materials have been decomposed by the acid and dissolved, the solution is freed from any excess of bromine by boiling it, and is then filtered from any undissolved residue. In this filtrate the oxidised sulphur is precipitated by barium chloride in the usual way.

With a view of testing the accuracy of this process, the author has determined the amount of sulphur absorbed by the bases in the crucible from the gases of the flame. This was found to amount in one hour to about 0.15 milligramme for one gramme of the magnesia mixture, or to 0.23 milligramme for $1\frac{1}{2}$ gramme. By employing porcelain crucibles heated in a muffle furnace, the reaction was complete in twenty or thirty minutes, and no absorption of sulphur by the charge could be detected. The method is accurate.

W. T. Neilson * mixes one gramme of the finely powdered coal or coke in which the sulphur is to be determined with two grammes of sodium carbonate and one half-gramme of manganese carbonate, and heats the mixture in a platinum crucible for an hour, this heating being effected in such a manner that only the bottom of the crucible is raised to redness. The carbon and sulphur is oxidised, and the mass in the crucible is then fused. It is then extracted with dilute hydrochloric acid, evaporated to dryness, taken up with hydrochloric acid, filtered, and the sulphuric acid precipitated by barium chloride in the ordinary manner. Owing to the absorption of sulphur from the gas flame, a "blind" assay should always be made.

IV.—GAS ANALYSIS.

Gas Analysis in Ironworks.—Professor Lunge † of Zurich has designed a gas volumetric apparatus which will be useful in ironworks, as it is arranged to avoid the usual laborious calculations for temperature and atmospheric pressure. The apparatus consists of a measuring

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 506.

† *Stahl und Eisen*, vol. xi. p. 845.

tube, a so-called reduction tube, and a pressure tube,—all three in communication, and each movable alone or jointly with the others. The description of this apparatus is accompanied by a sketch.

A modification of this apparatus is described by Professor F. R. Japp.*

* *Journal of the Chemical Society*, 1891, pp. 894-903.

STATISTICS.

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I.—UNITED KINGDOM.

Mineral Statistics.—According to the official reports of Her Majesty's Inspector of Mines, the production of coal in the United Kingdom in 1891 amounted to 185,479,126 tons. The production during the previous year was 181,614,288 tons.

The total quantity of iron ore raised was 12,777,689 tons, of which 7,229,150 tons were obtained from mines under the Coal Mines Act, 2,576,203 tons from mines under the Metalliferous Mines Act, and 2,972,336 tons from open works.

The production of pig iron in the United Kingdom in 1891 is stated * to have amounted to 7,228,496 tons, the production during the previous year having been 7,875,130 tons. The production of Bessemer steel ingots was 1,642,005 tons, and that of open-hearth steel 1,514,538 tons.

Imports and Exports.—According to the Board of Trade Returns, the exports from the United Kingdom during 1891 and 1890 were as follows :—

* *British Iron Trade Association, Bulletin No. 6.*

Description.	1891.	1890.
	Tons.	Tons.
Pig iron	840,773	1,145,268
Bar, angle, bolt, and rod	216,947	222,835
Railroad of all sorts	702,380	1,035,431
Wire of all kinds (except telegraph)	67,519	61,567
Hoops, sheets, boiler and armour plates	321,431	335,592
Tin plates	448,732	421,797
Old iron for remanufacture	111,338	149,902
Cast and wrought iron and all other manufactures	864,505	454,171
Unwrought steel	150,388	149,416
Manufactures of steel, or steel and iron	17,022	25,451
Totals	3,241,035	4,001,430
Coal, coke, cinders, and fuel	31,083,716	30,142,839
Coal shipped for steamers	8,536,495	8,096,405

The imports into the United Kingdom during the same years were as follows :—

Description.	1891.	1890.
	Tons.	Tons.
Iron ore	3,180,543	4,469,390
Bar, angle, bolt, and rod iron	77,416	92,899
Unwrought steel	8,436	8,144
Girders, beams, and pillars	74,035	71,833
Unenumerated	155,044	150,964

Iron Trade Exports to the United States.—The following table shows the influence of the M'Kinley Tariff on the exports of iron and steel from the United Kingdom to the United States.

Material.	Exports in		Increase in	Decrease in
	1890.	1891.	1891.	1891.
	Tons.	Tons.	Tons.	Tons.
Pig iron	101,991	46,636	...	55,355
Bars, angles, &c.	3,706	3,975	269	...
Railway iron, all kinds	11,208	3,849	...	7,359
Wire	5,059	3,223	...	1,836
Hoops, sheets, and plates	20,327	4,576	...	15,751
Tin-plate	321,109	325,145	4,030	...
Unmanufactured steel	19,576	27,425	7,849	...

The total British exports of iron and steel during the month of December 1891 showed a diminution of 15 per cent. when compared with the exports for the corresponding month of 1890.*

The Duration of the British Coalfields.—The duration of the British coalfields is discussed by Mr. T. Forster Brown,† and special consideration is given to a possible means of lessening the effect of the diminution of the supply. The amount of coal that is left in the country is doubtless sufficient to last for centuries, but the richest and most accessible deposits may be put as containing 16,000,000,000 tons. The duration of this, of course, depends on the increase of output, and upon this point a wide diversity of opinion exists; but the author is disposed to think that, on the whole, another quarter of a century of progress, at the rate of 2 to 3 per cent. per annum, will probably complete the occupation of the best of our coalfields, and attain probably the maximum of our national output of coal. This maximum output, estimated at an average of 250,000,000 tons per annum, may probably be maintained for another quarter of a century, to be followed by a slow but gradual reduction in the annual output, the annual rate of this reduction depending upon many conditions which it is, of course, impossible at the present time to predicate. The operation will, doubtless, be very gradual, commencing in the earlier-developed coalfields, and gradually extending to the larger coalfields of the Midlands and South Wales, and in the end increasing permanently the cost of producing coal. Upon a small scale the effect may already be observed in more than one of the older coal districts, where the working of thinner seams, at an increased cost, has both increased the cost of working and checked the increase of the rate of output, owing to the competition of coal produced from the newer coal districts at a cheaper rate. As a means of providing against the future, the author suggests that the repayment of the capital invested in railways, canals, docks, water, and lighting works, municipal and other loans, with the repayment of the National Debt, would give the relief required, and would leave the nation so much richer in many and important respects, and better able to deal, during the working of the inferior coal resources and after the exhaustion of the workable coal, when the country has to depend upon other resources than coal, with all the numerous contingencies which may arise than if the coal period had never arisen. If the views here

* *American Manufacturer*, vol. I, p. 199.

† Paper read before the British Association, Cardiff meeting.

expressed are approximately correct, the only opportunity which the nation will ever have of repaying the whole capital of this debt will be during the next fifty years or thereabouts.

II.—*AUSTRALASIA.*

Coal-Mining in New Zealand.—In the reports on the mining industry of New Zealand, dated 1891, the production of coal is stated to have been as follows :—

	Output of Coal.		Increase or Decrease.	Approximate Total Output to End of 1891.
	1889.	1890.		
	Tons.	Tons.	Tons.	Tons.
Bituminous coal	335,511	323,712	– 11,799	3,143,910
Pitch coal	87,445	124,593	+ 37,148	1,015,986
Brown coal	144,010	171,725	+ 27,715	2,113,460
Lignite	19,479	17,367	– 2,112	183,318
	586,445	637,397	+ 50,952	6,456,674

The number of mines at work in 1890 was 123, at which 1846 men were employed, giving an average output of 345 tons per head. Of the men employed, 1334 worked under ground.

The imports of coal in 1890 were 110,939 tons, as compared with 128,063 tons in the previous year, showing a decrease of 17,124 tons.

The exports of coal during 1890 amounted to 76,388 tons.

III.—*AUSTRIA-HUNGARY.*

Mineral Statistics of Hungary.—The following are the statistics relating to the production of the mines and ironworks of Hungary during the year 1890 : *—

* *Bányászati és kohászati lapok*, vol. xlix. Nos. 23 and 24.

Material.	Output.		Value.	
	1890.	1889.	1890.	1889.
	Metric Tons.	Metric Tons.	£	£
Iron ore	56,746	52,416	24,637	23,380
Iron ore exports	...	...	59,870	58,734
Coal	994,812	937,452	40,261	37,229
Lignite	2,249,098	1,955,226	527,918	484,505
Briquettes	25,183	22,797	16,573	14,979
Coke	20,026	10,291	14,445	6,951
Petroleum and asphalt	2,190	728	6,201	921
Pyrolusite	1,435	98	577	111
Manganese carbonate	2,389	...	702	...
Nickel and cobalt ores	340	366	4,047	4,427
Nickel and cobalt speise	59	47	1,954	1,749
Pig iron	285,102	225,940	856,154	645,628
Cast iron	14,005	12,860	88,889	84,685

Of the total number of workpeople in the mines and smelting establishments 44,053, or 83·7 per cent., were males, 1947 females, and 6132 children—3·7 and 12·6 per cent. respectively. Of these 24·3 per cent. were at work at iron-ore mines or ironworks, and 38·4 per cent. at the collieries.

There were 449 accidents, 60 of which were fatal, 145 severe, and 294 slight. Of the fatal accidents 1·7 per cent. occurred at iron-ore mines, and 84·6 at collieries. The accidents during 1890 showed a diminution of 6 per cent. as compared with the number that occurred in the previous year. The mining and metallurgical industries of Hungary have shown very marked progress during the past few years, as far as the coal and iron trades are concerned. A detailed statement is given, showing the production of each of the various blast-furnace works, and of the various collieries.

Mining Industry of Bosnia.—The government brown-coal mines at Zenica and Tuzla are gradually increasing their output.* After six years' existence, they have now attained an annual production of 50,000 tons. The coal is used almost exclusively in Bosnia, for the railways, for a few industrial establishments, and for household purposes. In the vicinity of Tuzla, it is believed that bituminous coal has been found. The output of the new brown-coal mine at Konjica is still small. Considerable progress has been made in the development of manganese mines, new mines having been opened at Banjaluka and Konjica by the company owning the Ceoljanovic mines.

* *Berg- und Hüttenmännische Zeitung*, vol. I. p. 423.

The iron industry has also made great advances. During the last decade, the industry in the vicinity of Vares annually diminished in importance. In the year 1890, however, the Government erected large ironworks for the manufacture of cast and wrought iron, on a scale to meet the requirements of the country.

The Steel Industry of Austria-Hungary.—F. Kupelwieser * discusses the progress which has been made in Austria-Hungary during the past twenty years, in the manufacture of ingot iron and steel. The production of acid and basic ingot metal has been as follows in the years mentioned—

Year.	Austria.		Hungary.	
	Acid.	Basic.	Acid.	Basic.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
1870	25,362	none	3,629	none
1875	84,502	none	13,203	none
1880	95,508	17,835	20,875	none
1885	129,329	76,821	72,653	none
1890	105,888	236,988	77,676	79,048

In 1886, 2740 tons of basic open-hearth metal was made in Hungary. In the northern portion of Austria, the acid process is rapidly passing into disuse, the make of metal having been only 12,151 tons in 1890, as compared with 35,258 tons in 1885.

The following table shows the respective outputs of the open-hearth and Bessemer processes in the same period :—

Year.	Bessemer Process.		Open-hearth Process.	
	Acid.	Basic.	Acid.	Basic.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
1870	25,491	none	3,500	none
1875	94,705	none	3,000	none
1880	87,881	17,835	28,502	none
1885	149,557	76,821	52,405	none
1890	149,660	138,021	33,904	178,015

In 1863 the total output of such ingot-metal was only 21 tons. It will be observed how rapid has been the progress made by the basic

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. pp. 495-498.

process in recent years; the output of acid metal, which in 1886 formed 54 per cent. of the total production, has now fallen to less than 37 per cent. of the total.

At the end of the year 1890, there were in Austria-Hungary:—

	Converters.	Open-hearths.
Southern Austria	15	20
Northern Austria	10	15
Hungary	12	13
Totals	37	48

Production of Petroleum.—There were existing in Austria, in 1890, 285 concessions for working petroleum, 266 of which were active—a decrease of 5 on the year. The workpeople employed numbered 3729, an increase of 538. The output amounted to 91,650 tons, valued at £273,570. This represents an increase on the year of 27·9 per cent. in quantity and 32·2 per cent. in value.

Of ozokerite mining companies 87 out of a total of 132 were at work. The production was 6880 tons, valued at £158,430—an increase of 5·8 per cent. in value and a diminution of 9·01 per cent. in quantity as compared with the output for 1889. The workpeople employed numbered 6136. The fatal accidents in oil and ozokerite mining numbered 24, the injured numbering 36, as compared respectively with 25 and 27 in 1889.*

Iron Trade Statistics.—The total number of mines at work in Austria in 1890 amounted to 659, an increase of 17 on the year, and of smelting establishments to 107, a number which showed no change. The miners numbered 108,784, and the smelters 12,894. About 7000 of this number were women and 6288 children. The collieries gave employment to 48,748 workpeople, the lignite mines to 39,508, and the iron ore mines to 5751, each number showing considerable increases over the corresponding numbers for 1889. In iron works 10,841 were employed, a decrease of 21 men on the year. The fatal accidents in the mines numbered 182, and 322 men were injured, as compared with 186 and 262. In addition, 2 women were killed

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 607.

and 5 injured. In the works there were no fatal accidents, but 13 men were badly injured in iron works and 6 at other smelting establishments.*

The Foreign Trade of Austria.—Dr. M. Caspaar† discusses the foreign trade of Austria between the years 1887 and 1889. With regard to iron and iron wares the value of the exports has steadily increased, whilst that of the imports has as steadily diminished. On the other hand, the value of the imports of machinery has rapidly increased, that of the exports changing but little in the interval. The values both of the exports and of the imports of each of the various kinds of fuel—charcoal, lignite, coal, and coke—have undergone practically no change except in the case of the lignite, in which instance an increase is shown both for exports and imports.

IV.—BELGIUM.

Iron Trade Statistics.—The Belgian production of iron and steel in 1891 and 1890 was as follows:—

Description.	1891.	1890.
	Metric Tons.	Metric Tons.
Forge pig iron	437,182	526,044
Foundry pig iron	65,436	69,183
Bessemer pig iron	185,438	192,009
Totals	688,056	787,236
Rails and plates	113,440	114,529
Various	389,642	399,782
Total manufactured iron	503,082	514,311
Steel ingots, &c.	243,729	221,296
Forged steel, rails, plates, &c.	213,517	201,810

The total production of coal in Belgium amounted to 19,865,345 tons in 1891, as compared with 20,365,960 tons in 1890, the total number of mines worked being 130. A decrease of 500,515 tons is thus shown.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxix. p. 604.

† *Ibid.*, vol. xxxix. pp. 486-490.

Imports and Exports.—The following table * shows the Belgian iron trade imports and exports for 1891 and 1890 :—

	Imports.		Exports.	
	1891.	1890.	1891.	1890.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Iron ore . . .	1,500,915	1,644,422	189,739	171,654
Pig iron . . .	192,551	245,956	16,992	11,463
Scrap iron . . .	22,666	18,320	6,961	11,702
<i>Wrought Iron—</i>				
a. Wire . . .	5,150	3,780	2,717	2,311
b. Rails . . .	269	158	25,801	12,853
c. Sheets . . .	1,607	1,874	47,737	45,707
d. Other kinds . . .	12,357	10,147	212,183	218,109
<i>Manufactured Iron—</i>				
a. Nails . . .	737	669	9,616	10,066
b. Other wrought iron manufactures . . .	3,822	3,671	30,790	35,260
c. Castings . . .	1,532	2,838	27,107	31,772
Steel blooms . . .	7,648	8,024	993	443
Steel rails . . .	843	755	60,174	73,862
Steel sheets and wire . . .	4,516	3,650	16,689	26,244
Wrought steel . . .	935	1,087	8,594	9,054
Rolling stock . . .	2,196	2,254	44,942	39,781
Machinery . . .	15,031	13,892	38,603	44,178

The imports and exports of coal and coke were as follows :—

	Coal.		Coke.	
	1891.	1890.	1891.	1890.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Imports . . .	1,624,714	1,719,534	140,523	65,839
Exports . . .	4,748,504	4,533,785	937,348	1,064,759

The exports of patent fuel in 1891 amounted to 354,295 tons, against 317,628 tons in the previous year.

* *Moniteur Industrielle*, February 4, 1892.

V.—*BRAZIL*.

Mineral Wealth of Brazil.—A bulletin on the mineral wealth of Brazil has been issued by the Bureau of the American Republics. Great deposits of coal and iron ore have been found, the state of Minas Geraes abounding with the latter in beds often lying at the surface and in masses. These deposits are worked only by small scattered furnaces, in which charcoal is the fuel used. Of these small furnaces there are five groups, producing about 3000 tons annually, the product being used in the surrounding districts in the manufacture of articles of home consumption. In the state of San Paulo there are also important deposits, and one of the mines is worked by the Government, whose works at Sorocaba with two furnaces produced in one year about 790 tons of pig iron. The ore contains about 67 per cent. of iron. In Santa Catherina there are deposits of hæmatite containing 20 to 30 per cent. of iron and 30 per cent. of manganese.

VI.—*CANADA*.

Mineral Statistics.—The summary of the mineral production of Canada for the year 1891, issued by the Geological Survey, contains the following items:—

	Tons.
Iron ore	68,979
Pig iron	23,891
Coal	3,400,479
Coke	57,084
Fire clay	250
Graphite	260
Limestone for flux	11,376
Manganese ore	274
Moulding sand	230
Petroleum (barrels)	755,298

The value of the mineral production of Canada in 1891 was the largest in her history, the most notable increases in output being in nickel and coal. The production of nickel amounted to 4,626,627 lbs., a production greater than that of all other countries.

The Mineral Production of Nova Scotia.—Mr. E. Gilpin,* in

* *Iron Age*, vol. xlix. p. 909.

his official report to the Department of Mines of Nova Scotia for the year 1891, states that the output has been as follows :—

Description.	1891.	1890.
Iron ore, tons of 2000 lbs. . . .	57,311	55,191
Manganese ore, tons of 2000 lbs. . . .	40	266
Coal, tons of 2240 lbs. . . .	2,044,784	1,984,001
Coke made, tons of 2240 lbs. . . .	34,148	36,736
Limestone, tons of 2000 lbs. . . .	18,000	35,000

The following table shows the production of coal in Nova Scotia in 1891, the figures relating to 1890 being given for comparison.

	1891.	1890.	Increase or Decrease.
	Tons.	Tons.	Tons.
Cape Breton	982,000	917,000	+ 65,000
Cumberland	465,693	438,599	+ 27,094
Pictou	409,000	430,500	- 21,500
Total	1,856,693	1,786,099	+ 70,594

The shipments of coke from the Albion exceeded 20,000 tons in 1891, and a small quantity was also made by the Inter-Colonial Company.*

Exports of Nickel.—During the twelve months ending June 30, 1891, the exports of nickel from Canada amounted to 5,352,043 lbs. This includes all the metal exported, whether in the form of ore, regulus, or speise.†

VII.—FRANCE.

Iron and Steel.—The production of pig iron for 1891 is stated to have been as follows :—

Description.	Forge Pig Iron.	Foundry Pig Iron.
	Metric Tons.	Metric Tons.
Coke pig iron	1,488,323	400,662
Charcoal pig iron	8,766	2,865
Mixed brands	662	17,907
Totals	1,497,751	421,434

* *Engineering and Mining Journal*, vol. liii. p. 118.

† *Iron Age*, vol. xlix. p. 503.

The total production of pig iron thus amounted to 1,919,185 metric tons, against 1,962,196 tons in 1890, the decrease being 43,011 tons.

The production of manufactured iron was as follows :—

Description.	1891.	1890.	Increase or Decrease.
	Metric Tons.	Metric Tons.	Metric Tons.
Puddled rails	514	388	+ 126
Merchant iron, puddled	560,708	...	...
" " charcoal	11,909	...	...
" " obtained by reheating	124,187	...	...
Total merchant iron	696,799	706,811	- 9,512
Plates, puddled	102,96	...	...
" charcoal	2,503	...	...
" by reheating	8,841	...	...
Total plates	114,308	118,670	- 4,362
Total production	811,621	825,369	- 13,748

The production of steel as ingots amounted to 725,290 tons, the production of merchant steel being as follows :—

Description.	1891.	1890.	Increase or Decrease.
	Metric Tons.	Metric Tons.	Metric Tons.
Bars	298,551	288,020	+ 10,531
Rails	194,162	176,497	+ 17,665
Plates	111,754	117,481	- 5,727
Totals	604,467	581,998	+ 22,469

Coal.—The output of the French collieries is stated to have been as follows :—

Description.	1891.	1890.	Increase.
	Metric Tons.	Metric Tons.	
Coal and Anthracite	25,676,463	25,591,545	...
Lignite	523,282	491,673	...
Totals	26,199,745	26,083,118	+ 116,627

Imports and Exports.—The French imports and exports of iron ore, iron, steel, and fuel during the years 1891 and 1890 were as follows :—

Description.	Imports.		Exports.	
	1891.	1890.	1891.	1890.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Iron ore	1,437,527	1,610,242	298,550	285,366
Pig iron	56,530	20,620	98,059	171,162
Manufactured iron	14,972	15,159	34,115	67,936
Steel	5,417	5,767	18,467	41,054
Scrap iron and steel	8,021	7,704	8,019	27,278
Forge scales	18,474	29,204	158,660	307,430
Coal	9,173,423	9,082,506	821,212	829,501
Coke	1,319,695	1,292,453	58,420	75,329

Of iron and steel imported and exported after manufacture the quantities were a

Description.	Imports.		Exports.	
	1891.	1890.	1891.	1890.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Forge pig iron	55,469	53,524	45,652	43,315
Foundry pig iron	35,854	61,964	39,844	51,394
Charcoal pig iron	7,859	5,320	5,783	3,859
Coke pig iron	9,934	7,348	9,423	6,159
Plates	5,808	3,672	4,220	3,494
Steel	2,603	2,556	1,693	2,982
Totals	117,527	134,384	106,615	111,203

The Consumption of Rails.*—The quantity of rails delivered to the various French railway companies amounted to 112,857 tons in 1891, as compared with 66,844 tons in 1890. The Chemin de fer d'Orléans took the largest amount, namely 23,700 tons.

Iron Industry of Meurthe-et-Moselle.—In Meurthe-et-Moselle there are 53 smelting furnaces, of which 44 are at work, owned by 19

* *Industries*, vol. xii. p. 246.

works. The daily production of foundry pig iron in these furnaces is 1735 tons, of forge pig iron 995 tons, and of basic steel 400 tons, the latter being made at Longwy.*

VIII.—GERMANY.

Iron Trade Statistics.—The following table gives the details relating to the production of iron ores, fuel, and pig iron in Germany and Luxemburg in the year 1890 †:—

	Production. Metric tons.
Coal	70,237,808
Lignite	19,053,026
Petroleum	15,226
Asphalt	51,144
Graphite	4,355
Iron ore, Germany	8,046,719
Iron ore, Luxemburg	3,359,413
Pig iron, charcoal, Germany	24,141
Pig iron, coal and coke, Germany	4,075,396
Pig iron, coal and coke, Luxemburg	558,913

Production of Pig Iron.—The production of pig iron in Germany, in 1891, is estimated by the German Iron Trade Association to have been as follows, not calculating charcoal iron or scrap :—

Description.	1891.	1890.
	Metric Tons.	Metric Tons.
Forge pig iron and spiegeleisen	1,747,130	1,862,895
Acid Bessemer pig iron	384,196	2,135,799
Basic Bessemer pig iron	1,704,279	
Foundry pig iron	616,414	657,820

The production of pig iron was thus rather more than 100,000 tons less in 1891 than in 1890. The figures for 1890 are the official ones. ‡

The production of pig iron has been as follows in the years men-

* *Industries*, vol. xii. p. 150.

† *Chemiker Zeitung*, vol. xv. p. 1799.

‡ *Stahl und Eisen*, vol. xii. p. 201.

tioned, the excess of imports over exports, or of exports over imports, being also shown : *—

Year.	Production.	Excess of Imports.	Excess of Exports.	Consumption.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
1891	4,452,019	79,025	...	4,531,044
1890	4,563,025	246,858	...	4,809,883
1889	4,387,504	164,586	...	4,552,090
1888	4,229,484	51,715	...	4,281,199
1887	3,907,364	...	108,905	3,798,459
1885	3,687,434	...	27,089	3,660,345
1883	3,469,719	...	35,903	3,433,816
1881	2,914,009	...	62,324	2,851,685

Imports and Exports.—The imports and exports of iron ore, iron, and steel of the German Customs Union, in the year 1891, were as follows : †—

	Imports.		Exports.	
	1891.	1890.	1891.	1890.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Iron ore	1,408,025	1,522,501	1,984,428	2,208,480
Scrap iron	5,058	19,111	59,112	40,788
Total pig iron	244,256	385,328	111,177	116,922
Blooms, ingots, &c.	654	1,189	42,458	24,141
Iron and steel manufactures	75,831	84,013	992,350	813,621
Machinery	39,887	53,869	83,309	80,311

Production of Coal.—At the Bochum meeting of the Society for Mining Interests, Dr. Reismann ‡ stated that the production of coal in 1891 promised to exceed that of 1890 by 4·3 per cent. From 1860 to 1870 it increased by 156 per cent., and by 1890 the increase was 90 per cent. Five new pits with a production of 1050 tons daily are to be opened up in 1892.

The Progress of the German Iron Trade.—H. Rentzsch § tabulates the following official statistical information relating to the iron trade of Germany, including Luxemburg, in the years mentioned :—

* *Stahl und Eisen*, vol. xii. p. 246.

‡ *The Colliery Guardian*, vol. lxiii. p. 65.

† *Ibid.*, vol. xii. p. 244.

§ *Stahl und Eisen*, vol. xii. pp. 80-83.

	1888.	1889.	1890.
Iron ore produced, tons	10,664,807	11,002,187	11,406,132
Producing mines	663	720	755
Value of ore per ton, shillings	3·74	4·22	4·19
Workpeople	36,009	37,762	38,837
Charcoal pig iron produced, tons	26,741	24,927	24,142
Coke and mixed fuel pig iron, tons	4,310,880	4,499,631	4,634,310
Value per ton, shillings	44·11	48·04	57·44
Producing works	111	108	108
Ore smelted, tons	11,020,641	11,489,975	11,908,846
Workpeople	23,046	23,985	24,846
Existing blast furnaces	271	264	268
Furnaces in blast	211	213	222
In blast, weeks	10,103	10,436	10,480
Castings made, tons	838,251	989,621	1,027,384
Value per ton, shillings	164·22	174·73	181·62
Pig and scrap iron melted, tons	965,347	1,137,228	1,181,278
Producing works	1,099	1,119	1,148
Workpeople	53,326	59,437	63,960
Weld iron, unmanufactured, tons	85,845	76,513	72,405
Value per ton, shillings	74·17	84·87	95·66
Weld iron manufactures, tons	1,558,797	1,673,449	1,486,658
Value per ton, shillings	120·87	133·20	150·38
Producing works	270	261	255
Workpeople	51,779	53,536	53,970
Steel, unmanufactured, tons	564,102	670,040	618,316
Value per ton, shillings	83·65	86·79	96·32
Ingot iron, manufactured, tons	1,298,574	1,425,439	1,613,783
Value per ton	140·60	155·67	166·83
Producing works	101	111	115
Workpeople	42,256	48,371	52,823
Coal produced, tons	65,386,120	67,342,171	70,237,808
Value per ton, shillings	5·27	5·77	7·66
Workpeople	225,462	239,954	262,475
Lignite produced, tons	16,573,963	17,631,059	19,053,026
Value per ton, shillings	2·47	2·51	2·61
Workpeople	29,630	31,140	33,161

The total number of workpeople employed in the iron ore mines and the iron and steel works was respectively 206,416, 223,091, and 234,436 in the three years under consideration.

Production of Pig Iron in Prussia.—The statistics relating to the production of pig iron in Prussia during 1890 are as follows : *—

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. p. 134.

Material.	Number of Producing Works.	Production.	Value.
Charcoal pig iron . . .	13	Metric Tons. 19,863	£ 134,619
Coal and coke pig iron . .	68	3,268,505	9,690,885

Of this quantity of pig iron 387,238 tons was foundry pig iron, 1,539,540 tons was suitable for ingot metal manufacture, and 1,322,163 tons for the manufacture of weld iron.

Production of Fuel in Prussia.—Provisional statistics * show the output of coal and lignite in Prussia to have been as follows in 1891, the statistics for the previous year being also given :—

Material.	Output.		Active Mines in 1891.
	1891.	1890.	
	Tons.	Tons.	
Coal	67,523,311	64,873,545	340
Lignite	16,818,845	15,499,977	405

The workpeople employed in 1891 numbered 251,312 in the collieries and 28,933 in the lignite mines, as compared respectively with 233,308 and 26,536 in 1890.

Accidents in Prussian Mines.—In the year 1890 there were employed at Prussian mines 341,904 workpeople, of whom 768 met with fatal accidents, an increase of 52 accidents and 24,822 workpeople as compared with the numbers for the preceding year. The collieries gave employment to 234,572 workpeople, 618 of whom met with fatal accidents during the year. There were 32 explosions causing loss of life, and 84 others causing injuries other than fatal ones. The total loss of life was due to the following causes : †—

* *Stahl und Eisen*, vol. xii. p. 207.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. pp. 135-136.

By explosions	78
Through shot firing	24
By falls of roof	289
On inclines	90
During ascent and descent of workpeople	14
By falls in shafts	46
By materials falling in shafts	8
By the cage	9
From other causes in shafts	9
By hauling in levels	40
Choke damp	21
By engines	13
By inbursts of water	2
At surface	93
From other causes	32
Total	768

Mineral Statistics of Saxony.—According to the official statistics,* the production of coal in the kingdom of Saxony, in the year 1890, amounted to 4,150,842 tons, and that of lignite to 848,053 tons, the output per miner being 207·12 tons in the collieries and 366 tons in the lignite mines. The production of iron ore amounted to 10,807 tons, valued at £2615, and that of manganese ore to 792 tons, valued at £602.

IX.—INDIA.

Iron Manufacture in India.—There appear to be at least four distinct places in India where iron could be produced from local sources. At Raneegunge the ore can be obtained at less than a shilling per ton at the furnaces, and there is a seam of limestone 12 feet thick, and fireclay is found in connection with the coal. In the Wardha valley, ore, coal, and limestone occur near enough together for successful working. The limestone is of good quality, but the Waroro coal unfortunately contains a large percentage of ash, and is not suitable for foundry work. Certain seams in this valley, however, contain as much as 65 per cent. of carbon. In Cutch there is ore, but only slaty coal. If the southern fields are as rich as is said it would pay to use charcoal for smelting.†

* *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1891, pp. 1-175.

† *The Indian Engineer*, vol. xii. pp. 34-35.

X.—*ITALY.*

Mineral Statistics.—The production of iron ore in Italy in 1890 amounted to 220,702 tons. There were 44 iron ore mines, and 2434 workmen employed.

The production of manganese ore during the same year was 2147 tons, that of lignite 2817 tons, and that of petroleum 177 tons.

XI.—*JAPAN.*

Imports of Iron and Steel.—The following details of the import trade of Japan have been given.* In 1890 Japan imported pig iron, bars, rods, nails, &c., to the value of £235,000 from England, about one fourth of that value from Germany, and from France about £4000. The English imports decreased in value as compared with the previous year. Pipes and tubes amounted to £23,000. The nails imported are mostly of German manufacture, English imports having fallen from £68,000 in 1888 to £27,000 in 1890. The value of steel imports from England was £32,000, from France £4600, and from Germany less than £1000. Practically all the cutlery, worth £3000, came from Sheffield. Locomotive engines were valued at £95,000 from England, £16,000 from Germany, and half that amount from the United States. Other engines and boilers amounted to £69,000.

XII.—*ROUMANIA.*

Production of Petroleum.—A. O. Saligny, N. Cuen, and C. J. Istrati,† state that the production of unrefined petroleum in Roumania has been as follows in the years mentioned:—

Years.	Output. Tons.
1887-1888	33,000
1888-1889	38,790
1889-1890	45,720
1890-1891	62,150

* *Iron and Coal Trades Review*, vol. xliii, pp. 784-785.

† *Cercetari a supra pacurilor din Romania*, 1891.

This last output was derived from the following districts in about the quantities named: Bacau, 12,000 tons; Buzeu, 9500 tons; Prakhova, 16,500 tons; Dambovita, 24,500 tons.

XIII.—RUSSIA.

Iron and Steel.—The production of iron and steel in Russia is stated * to have been as follows in 1888 and 1889:—

Description.	1888.	1889.
	Metric Tons.	Metric Tons.
Pig iron	667,470	798,679
Finished iron	364,857	431,266
Steel	222,470	263,936

Coal.—According to the official statistics the output of coal for 1889 from the 337 existing pits was: †—

	Tons.
Bituminous coal	5,345,200
Anthracite	713,060
Brown coal	60,300
Total	6,118,560

The outputs of the various coalfields were:—

	Tons.
Donetz	3,062,404
Poland	2,437,210
Moscow	301,570
Ural	258,710

The total output showed an increase of 1,012,000 tons over the previous year. Two fresh fields were discovered in the Government of Irkutsk, in Siberia.

There were 43,275 miners employed, and the output was 141·3 tons per man.

The imports of coal for 1889 were 1,843,330 tons, as compared with 1,500,000 tons for the previous year.

The quantity of fuel used in the Russian railways is reported ‡ to have been as follows:—

* *British Iron Trade Association*, Bulletin No. 1.

† *The Colliery Guardian*, vol. lxiii. p. 663.

‡ *Industries*, vol. xii. p. 241.

Description.	1889.	1890.
English coal, tons . . .	138,000	108,000
Naphtha, products, tons . . .	208,800	283,700
Wood, cubic fathoms . . .	655,000	601,000
Lignite, tons	6,541	6,316
Coal, tons	1,258,000	1,212,000

Further discoveries of coal are announced in the Donetz basin at a place about thirteen miles from Taganrog. The seam is extensive and of good quality. The amount shipped from this district was 2,100,740 metric tons in 1889 and 1,957,070 tons in 1890.

Steelworkers' Wages in Russia.—A recent communication from St. Petersburg on the subject of crucible steel manufacture in Russia states that each shift comprises one head melter, three crucible drawers, and one fireman for the furnaces and for opening the covers during casting. The shift at the gas producers consists of one head workman and two firemen. At the furnace the head man earns 2·40 roubles per shift, the crucible drawers 1·60 roubles, and the fireman 1·00. At the producers the wages are 1·15 and 1·00 roubles. Wages are paid in paper roubles, which are less in value than the silver rouble, the latter being about two shillings.*

Petroleum at Baku.—The yield of petroleum from the Baku district is rapidly increasing, the output in 1890 having been 16·3 per cent. in excess of that of the previous year, and the output during the first half of 1891 no less than 190,000,000 poods of 36 lbs., as compared with the total output in 1889 of 203,500,000 poods.† Of this 190,000,000 poods, 181,000,000 were derived from the Balakhano-Sabountchi district, where the wells during the first six months of 1891 increased in number from 273 to 335. Thirteen million poods of the oil came from the Bibi-Eybate district, where the number of wells increased during the above-mentioned period from three to thirteen; and 6,000,000 poods from the Romany district, where the number of wells remained unchanged. Included under the term "wells" are no less than twelve springs of oil. The average depth of the active wells is 96 sangrenes (7 feet), or 112 fathoms, in the first of the districts named above, 140 fathoms in the second, and 103½ fathoms in the Romany

* *Engineering*, vol. liii. p. 377.

† *Journal de la Chambre de Commerce de Constantinople*, November 14, 1892. 1892.—i. 2 L

field. Excluding the springs, the average production of the wells of these districts is respectively 2863, 5616, and 4007 poods, increasing, that is, with the depth of the well. In the Romany district naphtha is only found at considerable depth, and the cost of working is therefore high. The Arafeloz naphtha spring ran for eight hours during the spring of 1891, after a period of cessation, and yielded 20,000 poods of oil.

XIV.—SPAIN.

The Iron Trade of Spain.—Within recent years the Spanish Government has instituted a Statistical Department, dealing with the mines and metallurgical works of the kingdom, and details have been published for the year 1890. The *Revista Minera, Metalúrgica y de Ingeniería*,* has collected other statistics relating to 1891, and these are as shown in the following tables, the statistics for 1890 being those officially published. In 1890 the forty-nine provinces of Spain contained 2467 productive mineral concessions, giving employment to 56,853 workpeople, and yielding mineral valued at the mines at 97,422,688 pesetas (about £3,896,000).

Coal.—The production of coal was as follows in the years mentioned:—

Provinces.	1890.	1891.
	Metric Tons.	Metric Tons.
Oviedo	620,704	700,000
Cordova	241,778	236,000
Palencia	97,281	130,000
Seville	89,796	100,346
Gerona	66,641	40,981
Leon	20,537	22,000
Ciudad Real	42,465	55,623
Burgos	577	1,050
Totals	1,179,779	1,286,000

Lignite.—The following statistics show similar details referring to the output of lignite:—

* Vol. xliii. pp. 1-3, 9-11, 17, 18.

Province.	1890.	1891.
	Metric Tons.	Metric Tons.
Guipúzcoa	11,066	11,012
Barcelona	7,505	6,089
Lérida	6,100	4,684
Baleares	4,070	4,528
Teruel	964	1,141
Santander	598	693
Totals	30,303	28,147

The consumption of fuel in Spain has been as shown in the following table during the years mentioned :—

Description.	1860.	1870.	1890.	1890.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Production of coal	320,899	621,832	825,790	1,179,779
Production of lignite	18,952	40,095	21,338	30,303
Imports of coal and coke	452,479	566,911	881,860	1,840,310
Total consumption	792,330	1,228,838	1,728,988	3,050,392*

In 1870 the metallurgical industry of Spain consumed 450,000 tons of fuel ; in 1890 this consumption had risen to 1,100,000 tons.

Coal is mined in the north of Spain in the Asturias, Leon, and Palencia ; in Central Spain at Belmez, Cordova, and at Puertollano, Ciudad Real ; in Southern Spain, at Villanueva del Rio, Seville ; and in Eastern Spain, at San Juan de las Albadesas, Gerona.

Lignite is mined chiefly in the eastern portion of Spain. Here, in the province of Alicante, marine tertiary lignite is being mined at Alcoy ; tertiary lacustrine lignite at Calaf, in Barcelona ; cretaceous deposits at Berga, in the same province, and at Utrillas in the province of Teruel ; and, finally, jurassic lignite deposits are being actively worked at Préjano, Turruncún, and Villaroya, in the province of Logroño.

Iron Ore.—The exports from the port of Bilbao have been as follows :—

* This total is given as 3,320,392 in the *Revista Minera*. The coke in this tabular statement is stated to have been converted into coke. Probably in the above case this was not done.

Years.	Exports. Tons.
1879	1,117,836
1881	2,500,532
1883	3,378,230
1885	3,295,982
1887	4,170,422
1889	3,854,635
1890	4,272,918
1891	3,350,000

While the exports have thus shown a considerable diminution during the past year, there has been a largely increased home consumption.

Iron ore is mined in the north of Spain—in the provinces of Biscaya and Santander, where excellent Cretaceous ores occur; at Olviedo in the Asturias, where the ores are Devonian and siliceous. In Central and in Eastern Spain no iron ore is being mined on any scale; but in Southern Spain important deposits of manganiferous and magnetic ores are being mined in the provinces of Almeria, Murcia, Malaga, and Granada.

The total quantity of iron ore produced in Spain in 1890 amounted to 5,788,743 tons, valued at 28,271,021 pesetas (about £1,131,000). The iron ore concessions producing ore numbered 292, and the work-people employed, 12,076. Ten concessions were mined for manganese ore, employing 134 men, and yielding 832 tons of ore, valued at 13,115 pesetas (£520).

Pig Iron and Steel.—Biscaya and the Asturias are the two provinces of Spain where the iron industry is now concentrated. In the first of these, the more important companies are the Sociedad de Altos Hornos de Bilbao, La Vizcaya, and the La Francisca works. At the first-mentioned of these there are not only blast-furnaces, but also Bessemer converters and open-hearth furnaces; and steel rails are being made for the Spanish railways. The Vizcaya is another large works, and in 1892 it is proposed to erect “a double Siemens furnace, with regeneration of the carbonic anhydride for puddling, with considerable economy and less loss of metal.” This works is the largest Spanish producer of open-hearth metal, which it exports as a rule to Italy; but in 1891 a large proportion of its output went to Glasgow. A number of smaller ironworks exist in Biscaya, and there are some larger ones in the Asturias, notably the Fábrica de Mieres. A 10-ton open-hearth furnace was completed and put into active work, during the past year, at the Trubia arsenal.

The total quantity of pig iron produced during 1890 was 179,433 tons, of malleable iron 63,933 tons, and of steel 63,011 tons, the producing works numbering 22, and giving employment to 7985 work-people. These works possessed 39 hydraulic engines, having a total horse-power of 1266, and 256 steam engines with a total horse-power of 23,624.

Iron Trade Exports and Imports.—The Spanish imports and exports have been as follows in the years mentioned : *

Imports.	1889.	1890.	1891.
	Metric Tons.	Metric Tons.	Metric Tons.
Coal	1,335,809	1,431,623	1,675,000
Coke	279,144	286,081	250,000
Forge pig iron	27,937	34,335	30,000
Foundry pig iron	12,685	16,580	18,000
Finished iron	49,850	61,717	49,000

The exports of pig iron and of iron and manganese ores have been as follows :—

Exports.	1889.	1890.	1891.
	Metric Tons.	Metric Tons.	Metric Tons.
Iron ore	5,051,613	5,708,811	4,500,000
Manganese ore	8,187	5,570	1,000
Pig iron	65,471	67,446	68,000

The proportion borne by the value of the total exports of minerals and metals from Spain to the total of all exports is 23 per cent., and the value of the ores and metals imported amounts to 8 per cent. of the total value of the whole imports into Spain.

XV.—UNITED STATES.

Mineral Statistics.—The United States Geological Survey has recently published its annual volume of statistics. The following figures for 1890 show the yield and value of the various materials mentioned :—

* *Revista Minera, Metalúrgica y de Ingeniería*, vol. xliii. p. 19.

Description.	Statute Tons.	Value.
		Dollars.
Pig iron	9,202,703	151,200,410
Nickel	100	134,093
Bituminous coal	99,392,871	110,420,801
Pennsylvania anthracite	41,489,858	61,445,683
Limestone for flux	5,521,622	2,760,811
Ozokerite, refined	156	26,250

The total value of the metallic products obtained in the United States in 1890 amounted to 307,334,207 dollars, and that of the mineral products to 334,959,893 dollars. The total value was 64,000,000 dollars in excess of the value of the yield for 1889, and 103,000,000 dollars in excess of the value of the yield during 1888.*

Production of Iron and Steel.—Mr. J. M. Swank † states that the production of pig iron in the United States during the second half of 1891 was the greatest on record for any similar period, having amounted to 4,911,763 statute tons, making a total of 8,279,870 tons for the year. The increased consumption has not equalled the increased production, the stocks at the end of the year being 596,333 tons, against 442,055 tons at June 30. There has been an increase during the year of 617,511 tons in the output of pig iron made from bituminous coal and coke, of 358,740 tons in the anthracite iron, and of 57,322 tons in the charcoal pig iron. The production of spiegeleisen and ferromanganese was 127,766 tons, as compared with 133,180 tons in 1890.

At January 1, 1892, the blast furnaces in blast in the United States numbered 305, with a weekly capacity of 188,082 statute tons, as compared with 302 furnaces and 167,599 tons capacity at January 1, 1891, and 333 furnaces and 174,038 tons at January 1, 1890.

The anthracite furnaces in blast at January 1, 1892, numbered 94 out of a total of 160 existing stacks, the active capacity being 38,307 tons. At January 1, 1891, the furnaces in blast numbered 101, and their capacity was 40,212 tons.

The blast furnaces using bituminous coal and coke numbered 252 at January 1, 1892, and of these 163 with a weekly capacity of 138,611 tons were in blast, as compared with 143 furnaces and a capacity of 112,153 tons in January of the previous year.

The charcoal blast furnaces numbered 121 at January 1 of this year, and 48 were in blast at that date, their weekly capacity being 11,164

* *Iron Age*, vol. xlix.

† *Ibid.*, vol. xlix. p. 165.

tons, as compared with 56 furnaces and 11,365 tons at January 1, 1891, and 59 furnaces and 11,485 tons at January 1, 1890.*

According to the statistics published by the American Iron and Steel Association, the production of Bessemer steel in 1891 in the United States was 1,219,874 tons.

Imports and Exports.—The statistics published by the United States Bureau of Statistics show the following imports and exports for the years mentioned : †—

Imports.	1891.	1890.
	Tons.	Tons.
Pig iron	67,179	134,955
Scrap iron and steel for remanufacture	44,429	56,277
Bar iron and steel	18,353	24,238
Hoop, band, or scroll iron or steel	871	21,177
Ingots, blooms, slabs, billets, and bars of steel . .	34,676	28,636
Sheet, plate, and taggers' iron or steel	11,882	9,041
Tin plates, terne plates, and taggers' tin	327,868	329,435
Wire rods of iron or steel	46,938	55,427
Wire and wire rope	4,309	4,610
Anvils	813	1,390
Chains	448	583

Exports.	1891.	1890.
	Tons.	Tons.
Pig iron	14,946	16,341
Band, hoop, and scroll iron	163	612
Bar iron	1,340	1,068
Ingots, bars, and rods of steel	538	154
Nails and spikes	5,483	6,820
Plates and sheets—		
Of iron	344	513
Of steel	104	214
Railroad bars and rails—		
Of iron	160	104
Of steel	11,079	16,844
Wire	11,873	10,405

American Oil Fields.—At the close of 1891 the position of the petroleum industry was as follows in the States named :—

* *Iron Age*, vol. xlix. pp. 70-71.

† *Ibid.*, vol. xlix. pp. 257-258.

Districts.	Number of Wells.			Initial Daily Production of New Wells.
	Completed.	Dry.	Being Drilled.	
Pennsylvania, New York, and } West Virginia . . . }	197	39	276	Barrels. 15,468
Ohio	96	17	63	3,059
Indiana	8	1	12	175

The production of petroleum during the month of December showed a very considerable decrease when compared with that of the previous month.*

The Connellsville Coke Trade.—The production of coke in the Connellsville region, and the value of the product, have been as follows in the years mentioned:—

Year.	Production.	Value.
	Tons.	Dollars.
1886	4,109,331	5,876,343
1887	4,290,343	8,413,672
1888	4,971,287	5,965,544
1889	5,825,826	8,156,156
1890	6,221,518	12,903,940
1891	4,929,960	9,366,944

During 1891 nearly 1200 new ovens were built in this district, the total erected rising during the year from 16,020 to 17,204.†

Lake Superior Iron Ore.—The total shipments of iron ore from the Lake Superior districts by lake or by rail during the season of 1891 amounted to 7,062,233 tons.‡ The mines of the Marquette range shipped 2,511,395 tons, the following being among the more important mines with their outputs:—

Mines of the Marquette Range.	Shipments. Tons.
Angeline	241,605
Buffalo	478,509
Champion	133,413
Cleveland	221,788
Iron Cliffs Company	278,270
Lake Superior	308,831
Republic	191,127
Winthrop	122,042

* *American Manufacturer*, vol. l. p. 70. † *Iron Age*, vol. xlix. p. 118.

‡ *Iron Ore*, through the *Iron Age*, vol. xlix. p. 113.

The shipments of the mines of the Menominee range reached 1,824,552 tons, the following being the outputs of the more important mines :—

Mines of the Menominee Range.	Shipments. Tons.
Chapin	488,749
Commonwealth	134,982
Dunn	162,721
Ludington	141,303
Curry	100,681

The exports from the mines of the Gogebic range somewhat exceed those from the Menominee range, they having amounted to 1,834,747 tons :—

Mines of the Gogebic Range.	Shipments. Tons.
Ashland	267,439
Carey	121,186
Mount Hope	105,607
Norrie	758,572
Pabst	130,226

The shipments of ore from the mines of the Vermilion range amounted to 891,539 tons. All of this came from two mines, the Minnesota and the Chandler, the former of which shipped 517,550 tons and the latter 373,969 tons.

The total shipments from the various ranges show a decrease of no less than 1,961,347 tons on the year, more than half of this being due to the diminished shipments of the mines of the Gogebic range.

The progress of iron ore mining on the Gogebic range during 1891 is reviewed by Mr. C. M. Boss.* On the whole this season has been unsatisfactory, on account of the stagnation in the iron market; but continuous work in exploiting and developing has been carried on, and there will be several new mines shipping ore this year. Boreholes at the Norrie and Hohland mine show abundance of ore at a depth of 1500 feet, and the same body of ore has been proved at the Durora mine. Further east, explorations are being carried on, and at the Mikado mine a 14-foot bed has been struck. Two or three of the mines have ceased working, but other mines have been opened up. The Wisconsin end of the range has hardly kept pace with the eastern, except in a few instances.

The Fuel Supply of the United States.—In the course of a sketch of the progress of twenty years in the economy of production

* *Engineering and Mining Journal*, vol. liii. p. 82.

and consumption of the fuel supply of the United States, Mr. J. Birkinbine * observes that it is some seventy years since anthracite was first mined in that country, and that it was not until 1842 that the production reached 1,000,000 tons. By 1864 the annual production increased tenfold, an amount that was doubled by 1873, and approximately again doubled by 1890, the production then exceeding 40,000,000 tons. The total output of the Pennsylvania region has been 750,000,000 tons, and the production in one year is nearly three times the total output of iron ore. The following figures show the advance in two decades :—

Description.	1870.	1880.	1890.
Anthracite, tons . . .	13,925,229	25,580,189	40,714,721
Bituminous coal, tons . .	15,356,619	38,242,641	85,383,059
Charcoal, bushels . . .	...	74,008,972	90,000,000
Wood, cords . . .	...	145,778,137	180,000,000
Petroleum, barrels . . .	5,260,745	26,286,123	34,820,306
Natural gas, value in coal dis- placed . . .	...	...	£4,000,000
Pig iron, tons . . .	1,832,876	3,375,912	8,553,374
Manufactured iron, tons . .	1,287,347	2,101,183	2,518,193
Steel ingots, tons . . .	...	1,022,956	3,988,327

The total output of coal in the United States is 75 per cent. of that mined in Great Britain, and their united production is 80 per cent. of that of the world. In the United States over 2,000,000 cords of wood are cut annually to make the 90,000,000 bushels of charcoal. Peat is used to a small extent only. The production of petroleum has grown in thirty-two years from 2000 to 35,000,000 barrels annually, the total production up to date being 450,000,000 barrels. Of this 40 per cent. is used as fuel, and displaces 4,500,000 tons of coal. Owing to the vast amount of fuel used, a very small percentage saving effects a very great economy. Owing to the various economies effected in its use, the present development of coal production is able to meet the demand, which it would not do if the methods in vogue in 1871 were still employed.

According to an estimate by General I. J. Wistar, the coal supply of North America will last 112 years. In the United States the coal measures cover an area of 219,080 square miles, excluding the beds of the Rocky Mountain territory, while in the whole of North America, after considerable experience of all the great coal

* *Transactions of the American Institute of Mining Engineers* (advance proof).

fields both in the States and in British America, the author is disposed to give the total area of coal exposures as not exceeding 250,000 square miles. The working thickness of the coal over this area is assumed to be 6 feet, yielding 800 tons per acre per foot. This gives a total of 673,013,000,000 tons. The consumption in 1889 was 126,097,779 tons, and the rate of increase has been nearly cent. per cent. in the decade. This rate continued for thirty years, reduced to 50 per cent. for the next forty years and further reduced to 33½ per cent. for another forty-two years, gives the total period of duration as 112 years.

The Iron Trade Industry of Ohio.—The Chief Inspector of Mines for the State of Ohio, gives, in his sixteenth annual report, the following statistics relating to the output of coal and iron ore in the state :—

Description.	1890.	1889.
	Tons.	Tons.
Blackband ore	41,848	70,398
Hæmatite	127,240	180,011
Coal	11,788,859	10,907,385

The coal mined by machinery in 1890 amounts to 1,148,449 tons, as compared with 248,449 tons in 1889.

The Earnings and Efficiency of American Workmen.—Mr. C. D. Wright* gives the following details relating to the wages obtained by the workpeople in the iron and steel works of the United States. In the manufacture of pig iron the average wages are as follows :—

	Dollars per Day.
Northern district of the United States	1·18 to 2·03
Southern district of the United States	1·22 „ 1·34
Continent of Europe	0·62 „ 1·01

The following are some details relating to a large number of families :—

* *Iron Age*, vol. xlviii. pp. 1016-1018.

Industry.	Families.		Own House	Expenditure per Family.				Income per Family.	
	Total.	Average Number.		Rent.	Food.	Other Purposes.	All Purposes.	House-band.	All Sources.
<i>United States—</i>				Dols.	Dols.	Dols.	Dols.	Dols.	Dols.
Pig iron	762	5.0	189	65.02	235.66	262.10	546.23	513.52	591.61
Bar iron	623	4.8	112	107.33	281.21	302.43	671.50	698.49	784.11
Steel	183	4.7	28	86.44	254.18	236.58	563.50	578.52	663.56
Bituminous coal	508	5.3	134	61.19	237.44	242.71	524.71	426.73	550.30
Coke	249	4.8	33	58.19	218.66	194.72	462.69	516.46	572.57
Iron ore	165	5.2	44	33.11	183.83	184.83	395.93	322.82	401.65
Total	2,490	5.0	540	74.58	243.65	254.50	555.81	534.53	622.14
<i>Europe—</i>									
Pig iron	76	5.0	...	38.35	214.65	173.22	426.22	350.11	444.94
Bar iron	251	5.2	6	41.36	196.13	176.93	413.09	337.41	442.35
Steel	201	5.2	10	41.23	249.13	193.99	482.30	442.89	530.10
Bituminous coal	194	5.6	2	45.47	240.01	159.96	444.73	361.26	482.08
Coke	29	5.3	1	35.35	201.50	140.15	375.78	298.25	382.57
Iron ore	19	6.6	12	31.38	174.60	178.85	365.91	254.07	348.71
Total	770	5.3	31	41.76	222.52	175.40	437.83	368.30	470.96
Grand total	3,260	5.1	571	65.50	238.66	235.82	527.94	495.27	586.43

XVI.—COMPARATIVE TABLES.

The World's Production of Iron and Coal.—For purposes of comparison the following summary of the production of pig iron in the principal countries of the world is appended :—

Country.	Year.	Production in Tons.
United Kingdom	1891	7,228,496
Austria	1890	655,750
Hungary	1890	285,102
Belgium	1891	688,056
Canada	1891	23,891
France	1891	1,919,185
Germany	1891	4,452,019
Italy	1889	13,473
Russia	1889	798,679
Spain	1890	243,366
Sweden	1890	451,442
United States	1891	8,279,870

A similar summary showing the production of coal is as follows :—

Country.	Year.	Production in Tons.
United Kingdom	1891	185,479,126
Australasia—		
New South Wales	1890	3,060,876
New Zealand	1890	637,397
Queensland	1889	265,607
Victoria	1889	14,496
Tasmania	1889	40,300
Austria, coal	1890	8,931,065
" lignite	1890	15,329,056
Hungary, coal	1890	994,812
" lignite	1890	2,249,098
Belgium	1891	19,865,345
Cape of Good Hope	1889	26,254
Canada	1891	3,400,479
France	1891	26,199,745
Germany, coal	1890	70,237,808
" lignite	1890	19,053,026
India	1889	2,045,359
Italy, lignite	1890	220,702
Japan	1887	1,492,000
Natal	1889	54,482
Russia	1889	6,118,560
Spain	1891	1,286,000
Sweden	1889	256,628
United States	1890	141,229,513

Progress of the Basic Bessemer Process.—The total make of iron and steel by the basic process during 1891 amounted to 2,880,535 tons, being an increase over the production of the previous year of 277,452 tons. The total production from the introduction of this process up to date is 16,328,500 tons. Of this total, 2,375,779 tons consisted of basic Bessemer metal, and 504,756 of basic open-hearth metal. The production by countries is as follows :—

Countries.	1891.		1890.	
	Total.	With under 0·17 per Cent. C.	Total.	With under 0·17 per Cent. C.
	Tons.	Tons.	Tons.	Tons.
England	436,261	350,818	503,400	351,404
Germany and Luxemburg	1,779,779	1,314,781	1,493,157	1,138,241
Austria	221,212	95,907	202,315	114,857
France	255,401	173,880	240,638	175,550
Belgium, Russia, and United States	187,882	111,172	163,573	111,963
Totals	2,880,535	2,046,558	2,603,083	1,892,015

With this about 700,000 tons of slag, containing about 36 per cent. of calcium phosphate, was produced, and mostly used as a fertiliser.

An application for the prolongation of the patents numbered 908, 3975, and 4063 of 1878; 131, 257, 1313, and 3531 of 1879; and 4285 of 1880, which relate to the manufacture of steel by the basic process, was refused by the Privy Council, after consideration, on February 24, 1892.* In the course of the evidence it was shown that Messrs. Bolckow, Vaughan, & Co., in consideration of a third share of the profits and a license upon easy terms, undertook the expense of erecting furnaces and plant, and putting the process to a practical test upon a commercial scale. In the year 1890 the make of steel by this process amounted in Great Britain to upwards of half a million tons, and on the Continent to over two million tons, being about one-seventh and nearly two-thirds respectively of the entire production of steel. It was contended that the profits, although admittedly large, were inadequate to the merit of the invention, but the prolongation was ultimately refused on the technical point that the profits of Messrs. Bolckow, Vaughan, & Co. did not fully appear in the accounts submitted, and that they would share in all further profits. Besides this, it was apparent from the tone of the Committee that the profits derived by the patentees, amounting to £128,000 from the English patents alone, were a sufficient remuneration, and that this alone, disregarding the technical points raised, would have caused the application to fail.

European Coal Production.—The comparative coal production of Europe is given † as follows to show the increase in the various countries :—

Year.	Great Britain.	Germany.	Austria.	France.	Belgium.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
1880	149,187,720	46,973,560	5,889,631	18,804,767	16,886,698
1887	164,713,729	60,333,984	7,796,150	20,809,982	18,378,624
1888	172,654,183	65,386,120	8,274,461	22,172,029	19,218,481
1889	179,747,392	67,342,171	8,592,876	23,851,912	19,869,980
1890	184,520,116	70,039,046	8,931,065	26,327,008	20,365,960
Increase.					
1880-1890	35,352,396	23,065,480	3,041,434	7,522,241	3,479,262
1887-1890	19,806,387	9,705,062	1,134,915	5,517,026	1,987,336
Increase.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1880-1890	23·7	49·0	51·6	40·0	20·6
1887-1890	12·0	16·0	14·5	26·5	10·8

* *Industries*, vol. xii. p. 256.

† *Glückauf*, vol. xxvii. p. 786.

BIBLIOGRAPHY.

The following is a list of the principal works relating to iron and steel published during the first half of 1892 :—

METALLURGY.

- BLAIR, A. A. "*Die chemische Untersuchung des Eisen.*" German translation by L. Rürup. 8vo, pp. 257, with 102 illustrations. Berlin. (Price 6s.)
- BOLLAND, S. "*The Iron Founder: a Comprehensive Treatise on the Art of Moulding.*" 8vo, pp. 382, with 308 illustrations. New York. (Price 2.50 dollars.)
- CAMPREDON, L. "*Les Moulages d'Acier.*" 8vo, pp. 160. Paris. (Price 3 francs.)
- CHATELIER, A. LE. "*Influence de la Température sur les Propriétés Mécaniques des Métaux.*" 8vo. Paris.
- CLAVENAD, C. "*Notice sur les Générateurs et Gastificateurs.*" 8vo, pp. 30. Paris.
- DEWEY, F. P. "*A Preliminary Descriptive Catalogue of the Systematic Collections in Economic Geology and Metallurgy in the United States National Museum.*" 8vo, pp. 256, illustrated. Washington.
- DINGEY, P. S. "*Machine Pattern Making, containing full-size profiles of gear teeth, and fine engravings, on full-page plates, illustrating manner of constructing numerous and important patterns and core-boxes.*" 276 illustrations. New York.
- "*Directory of the Iron and Steel Works of the United States, and a Complete List of the Iron and Steel Works of Canada and Mexico.*" Pp. 282. Philadelphia. (Price 4 dollars.)
- DITTE, A. "*Leçons sur les Métaux Professées à la Faculté des Sciences de Paris.*" Part II. 4to, pp. 671. Paris.
- EWING, J. A. "*Magnetic Induction in Iron and other Metals.*" London.
- HASLUCK, P. N. "*Milling Machines and Processes: a practical treatise on shaping metals by rotary cutters, including information on making and grinding the cutters.*" 8vo, 300 illustrations. London.
- HELSON, C. "*La Sidérurgie en France et à l'Étranger.*" Part I. The entire work will consist of two 8vo volumes of text, and a folio atlas of 200 plates. Paris. (Subscription price 80 francs.)

- HEMPEL, W. "*Methods of Gas Analysis.*" Translated by L. M. Dennis. Pp. 394, illustrated. London.
- MUKAI, T. "*Studien über chemisch-Analytische und mikroskopische Untersuchung des Mangantahls.*" 8vo, pp. 36, with 5 plates. Freiberg. (Price 2s.)
- PETITJEAN, G., A. HABETS, and A. GILLOX. "*Exposition Universelle Internationale de 1889 à Paris. Rapports du jury international. Classe 48. Matériel de l'exploitation des mines et de la métallurgie.*" 8vo, pp. 309. Paris.
- PONTHIERE, H. "*Traité d'Électro-Metallurgie.*" 2nd edition. 8vo, pp. 372. Louvain. (Price 10 francs.)
- SWANK, J. "*History of the Manufacture of Iron in all Ages, and particularly in the United States, from colonial times to 1891: also a short history of coal mining in the United States, and a full account of the influences which long delayed the development of all American manufacturing industries.*" 2nd edition. Pp. 574. Philadelphia. (Price 7-50 dollars.)
- SWANK, J. "*Statistics of the American and Foreign Iron Trades for 1891.*" American Iron and Steel Association. Philadelphia.
- VILLON, A. M. "*L'Éclairage, le Chauffage, et la Force Motrice par les Hydrocarbons Lourds.*" Paris.

MINING.

- AGUILLON, L. "*Législation des mines Françaises et étrangères.*" 2nd edition. 3 volumes. 8vo. Paris. (Price 40 francs.)
- "*Artesian Boring. Report presented to the New South Wales Government by the officer in charge, for water conservation.*"
- ATKINSON, A. A. "*A Key to Mine Ventilation.*" 8vo, pp. 157, illustrated. Scranton, Pennsylvania. (Price 1 dollar.)
- BALLING, K. "*Ueber das zur Ventilation von Grubenbauen erforderliche Luftquantum.*" 8vo, pp. 67. Teplitz. (Price 2s.)
- CASTELNAU, F. "*Préparation Mécanique des Minerais.*" 8vo, pp. 97. Paris. (Price 3 francs.)
- DAVIES, D. C. "*A Treatise on Metalliferous Mines and Mining.*" 5th edition. Pp. 548, illustrated. London. (Price 12s. 6d.)
- DAVIES, D. C. "*A Treatise on Earthy Minerals and Mining.*" 3rd edition. Pp. 394, illustrated. London. (Price 12s. 6d.)
- EMMENS, S. H. "*Explosives and Ordnance Material, considered with reference to some recent experiments with emmentite, gelbrite, and aluminium bronze.*" Pp. 93, illustrated. Baltimore.
- GIBSON, A. M. "*Report on the Coal Measures of Blount County, Alabama.*" 8vo, pp. 238. Montgomery, Alabama.
- GILPIN, E. "*The Iron Ores of Nova Scotia.*" Pp. 26, illustrated. Montreal.

- GUTTMANN, O. "*Blasting: a Handbook for the Use of Engineers and Others engaged in Mining.*" 8vo, pp. 179, illustrated. London. (Price 10s.)
- GUTTMANN, O. "*Handbuch der Sprengarbeit.*" 8vo, pp. 98, with 136 illustrations. Leipzig. (Price 6s.)
- HLENG, M. C. "*A Manual of Mining, based on a Course of Lectures delivered at the School of Mines of the State of Colorado.*" 8vo, pp. 428, illustrated. New York. (Price 4 dollars.)
- LOCK, C. G. W. "*Miner's Pocket-book.*" 8vo. London. (Price 12s. 6d.)
- "*Notizie sul Servizio Minerario e Geologico Raccolte per cura dell' Ispettorato delle Miniere nell' Occasione dell' Esposizione Nazionale di Palermo nel 1891-92.*" 8vo, pp. 106. Rome.
- ORTON, E. "*Geological Survey of Kentucky. Report on the occurrence of petroleum, natural gas, and asphalt rock in Western Kentucky.*" 8vo, pp. 233, illustration. Frankfort, Kentucky.
- PENROSE, R. A. F. "*Manganese, its Uses, Ores, and Deposits.*" 8vo, pp. 644. Little Rock, Arkansas. (This forms Vol. I. of the Annual Report of the Geological Survey of Arkansas.)
- PHILLIPS, H. J. "*Fuels, Solid, Liquid, and Gaseous.*" 2nd edition. London.
- PISANI, F. "*Comptoir Minéralogique et Géologique.*" Pp. 45, illustrated. Paris.
- POTTS, W. J. "*Colliery Directory and Register of Certificated Managers of Mines, 1891-92.*" North Shields. (Price 10s.)
- "*Reports of the Inspectors of Mines of the Anthracite and Bituminous Coal Regions of Pennsylvania for the Year 1890.*" 8vo, pp. 491, illustrated. Harrisburg, Pennsylvania.
- SCHULZ, W. "*Neues aus der Aufbereitung.*" 4to, pp. 8. Freiberg. (Price 9d.)
- TREPTOW, E. "*Grundzüge der Bergbaukunde.*" 8vo, pp. 381, with 230 illustrations. Vienna. (Price 4s. 6d.)
- WHITE, J. C. "*Stratigraphy of the Bituminous Coalfield of Pennsylvania, Ohio, and West Virginia.*" Bulletin No. 65 of the United States Geological Survey. Washington.
- WINSLOW, A. "*Preliminary Report on the Coal Deposits of Missouri.*" 8vo, pp. 226, with 131 illustrations. Jefferson City.

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